orrosion

Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS



SEPTEMBER, 1950

CORROSION PLAYS NO FAVORITES

CHEMICAL

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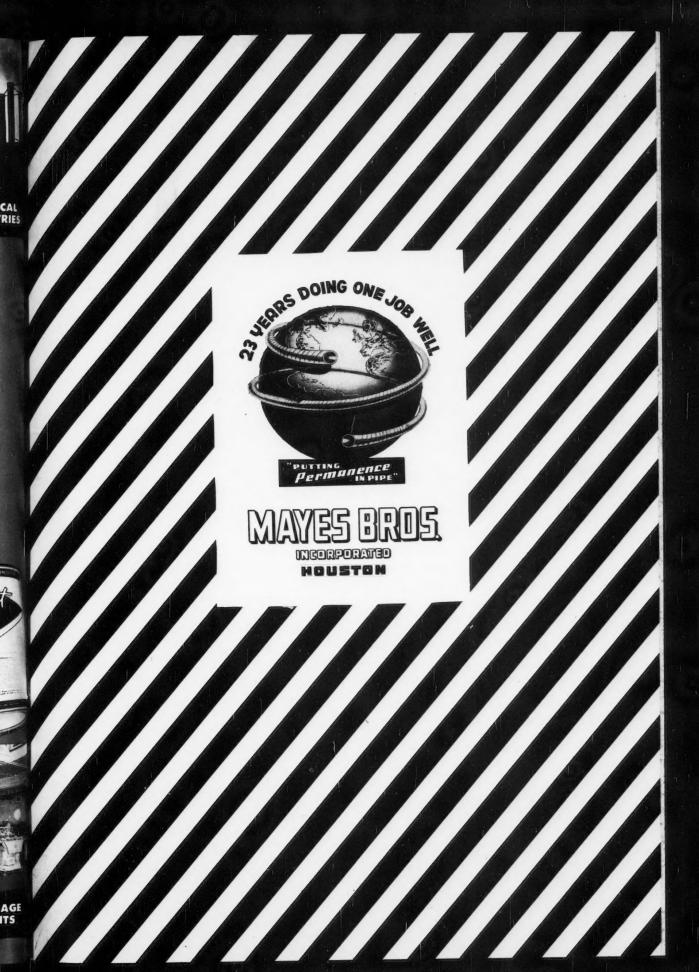
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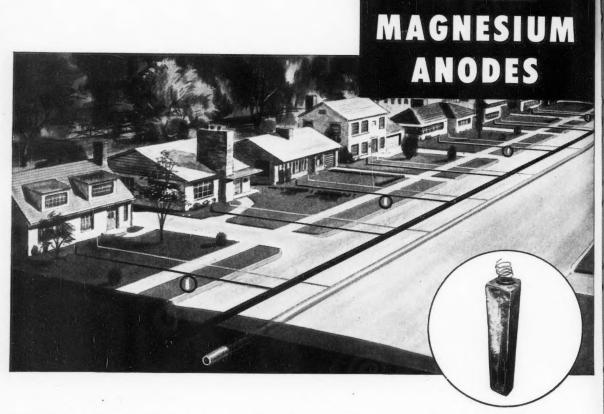
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Vol. 6

SEPTEMBER, 1950

No. 9



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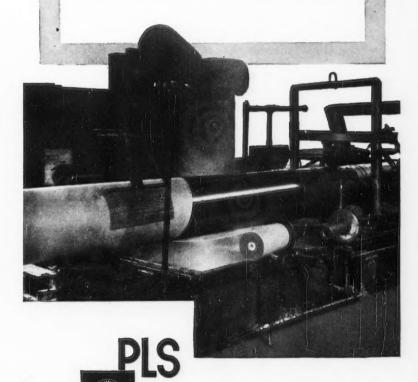
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Technical Committee Activities

Objectives of TP-5-Corrosion Problems in Handling and Processing Chemicals

By MARS G. FONTANA,* Chairman

S CHAIRMAN of the Technical Practices Com-A mittee of the National Association of Corrosion Engineers, I should like to make a plea for help on this committee's work before describing the activities of TP-5. More workers are needed to develop and promote this important function of our association. A person working on these committees improves his own stature by keeping up to date on developments, he gains valuable experience and information, he becomes more valuable to his company or employer as a result of the information obtained, he helps the NACE progress and, last but not least, he lends a hand in the fight against our common enemy -corrosion. Anyone interested is invited to contact e committee or sub-committee chairman involved. A directory of these chairmen is presented on page iv of this journal.

The handling and processing of chemicals represents a large portion of the existing corrosion problems and the cost of corrosion in this connection is tremendous. TP-5 was formed in 1948 to determine the materials that are used for handling various chemicals; the types of equipment and why; to obtain additional required information from chemical companies and have tests initiated to augment presently available information; and to ultimately draw up recommended practices for materials and methods for the construction of various types of chemical equipment, including metallic and non-metallic materials. This covers a broad scope and program and will require a long time to complete. As starting points in this work five fields of activity were selected and sub-committees formed.

The sub-committees of TP-5 with their scope of activities and membership are as follows:

Sub-Committee TP-5A—Materials for Handling and Manufacturing Sulfuric Acid. Chairman: S. W. Shepard, American Cyanamid Company, Calco Chemical Div., Bound Brook, N. J.

Members:

- C. L. Bulow, Bridgeport Brass Co., 30 Grand St., Bridge-
- port, Conn. J. Pat Casey, Jr., Crane Co., 836 S. Michigan Ave., Chicago,
- 5, Illinois. L. Fetner Fetner, Jr., Carnegie-Illinois Steel Corp., Research Lab., Vandergrift, Pa.

- W. Z. Friend, The International Nickel Co., Inc., 67 Wall St., New York 5,
- L. Hart, National Zinc Inc., Bartlesville, Oklahoma.
- The Duriron W. A. Luce, Co., Box 1019, Dayton 1, Ohio.
- C. Reichard, American Smelting & Refg. Co., Central Research Lab., Barber, New Jersey.
- J. J. Staiti, Allied Chemical & Dye Corp., General Chemical Div., P. O. Box 149, Long Island City, New York.



MARS G. FONTANA

Scope: This committee is interested in corrosion by sulfuric acid alone and also process solutions containing this acid. A major field of activity is involved because sulfuric acid is the major chemical used on a tonnage basis and is utilized in most of the process industries. Corrosion data and information on actual service experience are being compiled. The field has been divided into: fertilizers, petroleum refining, chemicals, coal products, iron and steel, other metallurgical uses, paints and pigments, industrial explosives, rayon and cellulose film, textiles and miscellaneous.

Sub-Committee TP-5B-Design of Equipment for Corrosive Service.

Chairman: C. M. Shigley, The Dow Chemical Co., Freeport, Texas.

- F. W. Davis, 1430 Widener Place, Philadelphia, Pa. W. J. Mead, Colgate-Palmolive Peet Co., 105 Hudson St.,
- W. J. Mead, Colgate-Palmonve Peet Co., 103 Fluuson St., Jersey City 2, N. J.
 J. T. Robbins, Peter A. Frasse & Co., Inc., 17 Grand St., New York 13, N. Y.
 S. W. Shepard, American Cyanamid Co., Calco Chemical Div., Bound Brook, N. J.
 E. D. Verink, Jr., Aluminum Co. of America, P. O. Box 1012, New Kensington, Pa.

Scope: This committee is interested in developing information on the importance of design in equipment for corrosive service. In many cases failures have occurred because of improper design of equipment and not because the material of construction or the process is at fault. Proper design often results in prolonged life of equipment. This is a factor that is often overlooked. This committee is concerned with

Professor and chairman, Department of Metallurgy and Director Corrosion Research Laboratory, The Ohio State University, Colum-

the physical shape and assembly of equipment and not particularly with selection of the materials of construction.

Sub-Committee TP-5C-Sub-Surface Corrosion by Alkaline Solutions.

Chairman: H. W. Schmidt, The Dow Chemical Company, Midland, Michigan.

Members:

Paul J. Gegner, Pittsburgh Plate Glass Co., Columbia Chemical Div., Barberton, Ohio.

Gustave Heinemann, Southern Alkali Corp., Corpus Christi,

F. Pogacar, Koppers Co., Koppers Building, Pitts-

burgh 19, Pa. E. H. Wyche, Lukens Steel Co., Coatesville, Pennsylvania.

Scope: This committee is interested in the sub-surface attack and cracking that often occurs in metals and alloys as a result of exposure to alkaline solutions. One type of this attack is commonly known as caustic embrittlement. One of the first functions of the committee is to assemble corrosion data and service experience on caustic solutions in order to define the areas of temperature and concentration where cracking is likely to occur. Considerable information already has been accumulated.

Sub-Committee TP-5D—Corrosion by Organic Acids and Bases in the Vapor Phase.

Chairman: F. L. Whitney, Monsanto Chemical Co., 1700 S. Second St., St. Louis, Mo.

Members:
L. D. Cook, Wyandotte Chemical Corp., North Plant, Wyandotte, Michigan.
F. W. Davis, 1430 Widener Place, Philadelphia, Pa.
G. F. Lockeman, Proctor & Gamble Co., Engineering Div., Ivorydale, Cincinnati, Ohio.
D. L. Miller, Shaples Chemicals, Inc., Wyandotte, Mich.

R. H. Potts, Supt. Chemical Div., Armour & Co., P. O.

Box 190, La Grange, Ill.

C. W. Swartout, Chief Engineer, Mallinckrodt Chemical Works, 65 Destrehen Ave., St. Louis, Missouri.

H. O. Teeple, International Nickel Co., 67 Wall St., New York 5, New York.

Scope: This committee is interested in corrosion by organic materials in the vapor phase. In many cases only corrosion by the liquid media are considered and as a result unexpected failures occur in the parts of equipment exposed to vapors. The effects of gaseous phases, decomposition products and condensation are being considered.

Sub-Committee TP-5E - Gasket Materials for Corrosive Service.

Chairman: L. D. Cook, Wyandotte Chemical Corp., North Plant, Wyandotte, Michigan.

Members C. L. Bulow, Bridgeport Brass Co., 30 Grand St., Bridge-

Paul J. Gegner, Pittsburgh Plate Glass Co., Columbia Chemical Div., Barberton, Ohio.
E. C. Gosnell, The Colonial Iron Works Co., 17643 St. Clair Ave., Cleveland, Ohio.

Scope: This committee is concerned with the performance and selection of gasket materials for corrosive services. Most equipment requires gaskets and too often improper gasketing results in high maintenance. Information on corrosion of gasket materials and on proper design and installation are being collected.

It is planned to present some of the results of the above sub-committee work during the Chemical Industry Symposium of the 1951 Annual Conference

and Exhibition of the NACE.

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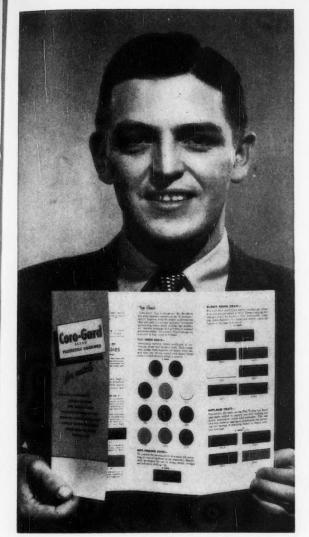


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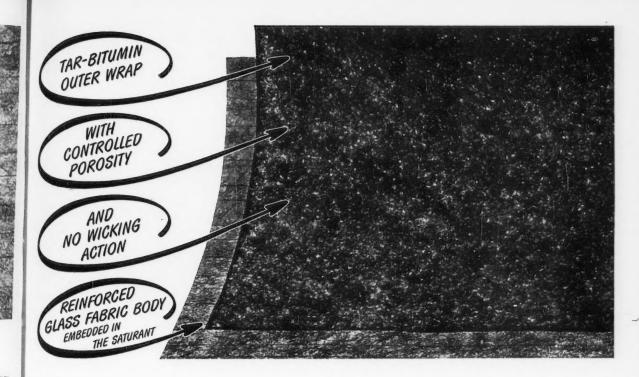
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- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
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Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.



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Corrosion of Metals in Fluorine And Hydrofluoric Acid*

By G. C. WHITAKER

L ARGE SCALE commercial production of fluorine was developed during World War II and methods of handling the gas in large quantities were essential to the success of the program. During the same period anhydrous hydrofluoric acid gained wide acceptance for the alkylation of hydrocarbons and the use of aqueous hydrofluoric acid expanded considerably. These new and expanded uses posed a great number of problems for the corrosion engineer.

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Platinum, the classical last resort for the chemist's corrosion problems in the past, is reported by Rudge¹ to be quite unusable in fluorine at 400° C and the burden of solving the corrosion problems for fluorine has fallen to the less noble metals.

Nickel and Monel were found by a number of investigators to show the most resistance to corrosion over wide ranges of temperature. Myers and De-Long² reported that these metals showed good resistance to fluorine up to 450° C and that mild steel was applicable up to 350° C. Landau and Rosen³ determined the corrosion rate of a large number of metals at varying temperatures and also found nickel and Monel to have excellent properties. Priest and Grosse⁴ stored fluorine at 150 to 300 psi at room temperature in copper and nickel cylinders and found no signs of corrosion after a year. Froning, Richards, Stricklin and Turnbull⁵ used steel and nickel cylinders to store and ship fluorine at 400 psi.

In work with fluorine at The Harshaw Chemical Company nickel metal has been found to give best results for a large number of reactions in which fluorine is used. At 600° C it has been noted that there is some slight pitting of nickel pipe but this was found in only one case and may have been caused by local organic contamination of the surface. In all work with fluorine, organic contamination should be rigidly excluded, especially at elevated temperatures. Local "hot spots," caused by the burning of organic material in contact with a metal, may raise the temperature to the kindling point and completely destroy the equipment. This point is readily demonstrated with steel wool which takes fire instantly when exposed to a stream of cold fluorine. However, when the steel wool is degreased by washing in ether and then dried it no longer is attacked by cold fluorine. Mild steel has been used almost exclusively in the fabrication of fluorine cells and has given exABOUT THE AUTHOR—After graduation from Miami University in 1927, George C. Whitaker joined the Harshaw Chemical Company at their Cleveland, Ohio, plant. Over the intervening years he rose to plant superintendent then transferred to the Research and Development Department to head an urgent World War II problem on fluorine. He went back into production to turn out materials for the atomic bomb project and is now manager of Technical Services.



Abstract

Experience gained over a period of years in the use of metal equipment for the production and handling of fluorine and for the production and shipment of hydrofluoric acid has resulted in an accumulation of information relative to the behavior of metals under various conditions. None of the common metals or alloys have been found to be universally applicable and even the nobler metals such as platinum and silver have developed shortcomings under certain conditions. Of the common commercial metals the nickel-copper alloys such as Monel have been found most versatile. However, severe corrosion has been encountered under some conditions. Nickel proved to be excellent for service with fluorine to relatively high temperatures Mild steel has been used extensively in fluorine cell construction and has proved adequate for the storage and shipment of anhydrous hydrofluoric acid. Steel drums and tank cars have been used for a number of years for the shipment of the higher strengths of aqueous hydrofluoric acid. Copper tubing, because of its convenience, and copper pipe have been used in hydrofluoric acid service but due to sensitivity to high velocity corrosion should be used with caution. The stainless steels have proved of little service because of a pitting type of corrosion. Lead, which was used almost exclusively in aqueous hydrofluoric acid service has been replaced by other metals and synthetic rubbers.

cellent service. Corrosion in the anode chamber where the metal is exposed continuously to the action of both fluorine and anhydrous hydrofluoric acid at temperatures close to 100° C is limited to the formation of protective film of iron fluoride. Cells have operated for periods of several years.

Both steel and copper pipe have been used for transporting fluorine from cells to process and no serious corrosion has been encountered in either case. For laboratory work copper tubing and brass compression fittings have been found to last indefinitely.

[★] A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

Lead gaskets used in fluorine cells were destroyed in a few weeks' time. The lead reacted to form a brittle white solid similar to that produced when lead is exposed to anhydrous hydrofluoric acid.

The stainless steels were subject to a pitting type of corrosion and were avoided in both fluorine and hydrofluoric acid service.

The corrosive properties of the halogen acids are shared by hydrofluoric acid. Along with its reducing properties it holds a unique position in its ability to dissolve siliceous materials. The corrosive action is further complicated by a change in properties from dilute to the higher strengths.

The early laboratory investigations with hydrofluoric acid were almost invariably conducted in platinum apparatus. Stahl⁶ in 1896 recommended lead for the preparation and commercial handling of the acid and this metal was used almost exclusively until the demand for stronger acid appeared. Where lead was suitable for acid up to 60 percent strength it failed rapidly at higher concentrations and at elevated temperatures.

Lead equipment for the reaction chamber in which fluorspar was treated with strong sulfuric acid had already been replaced by steel before the advent of anhydrous hydrofluoric acid. Because the steel reaction chambers which operated under relatively anhydrous conditions were satisfactory at the elevated temperature necessary to complete the reaction it was logical to suppose that steel would be suitable for handling the anhydrous acid.

Gore⁷ in his early researches reported that no hydrogen was evolved when iron was placed in anhydrous hydrofluoric acid and the acid subsequently has been found to have only a slight action on mild steel up to 55° C. Pieces of polished steel placed in the acid developed a slight film during one day of immersion and small amounts of hydrogen have been detected in the first gas withdrawn from steel cylinders of the anhydrous acid.

Friend and Teeple⁸ reported a corrosion rate of mild steel in the anhydrous acid at 0.018 ipy and Phillips Petroleum Company⁹ cited figures of 0.014 ipy for mild steel at 55° C. In early work by the writer's firm with the acid strips of steel placed in the liquid phase of a condenser showed a slight gain in weight after 30 days but actual loss after cleaning was so small that the corrosion rate was considered negligible.

The operation of a plant for the manufacture of anhydrous hydrofluoric acid for over a period of several years has substantiated the early reports of low corrosion rates on mild steel. Storage tanks, blow cases and shipping cylinders have been used continuously during this period with not a single failure due to corrosion.

The blow cases were used as collectors from the condensers and when filled with acid were pressured with dry air to transfer the acid to storage tanks. This alternate filling with acid and air has caused no difficulty. All transferring of acid from storage tanks also has been accomplished with air pressure.

Records of the history of several hundred steel cylinders used for shipping the acid have been kept

since the acid was first commercially available. These cylinders were made from Type 1008 open hearth steel according to ICC 4B Regulations which specifies a minimum thickness of 0.109 inches. At five-year intervals these cylinders were tested hydrostatically and measurement of temporary and permanent expansion made. No cylinders have been rejected during the retesting period.

Several of these early cylinders were flame cut so that their interiors could be examined. Samples taken from these cylinders showed after washing and polishing with steel wool a relatively smooth interior surface with a slight pitting. The interior surface, however, was in better condition than the outside surface which had been exposed to the atmosphere. Thickness of these samples have all been in excess of the 0.109 inch required by the specification.

In the case of aqueous hydrofluoric acid considerable work has been done to make the shipment of the acid safe and trouble free. In the earlier processes for the manufacture of the acid fluorspar was reacted with sulfuric acid in heated steel retorts and the gases produced by this action were absorbed by water contained in lead absorption towers and tanks. The finished acid was stored and shipped in lead containers.

Meiklejohn¹⁰ in 1925 patented a process for treatment of steel drums which rendered the steel passive to acid of not less than 60 percent strength. A passification crust was formed on the interior of the drum by filling the container with acid of 58 percent strength and holding for a period of 48 hours at 80° F. followed by a period of seven hours at 140° F. Washing of the drums with water after the treatment reduced the useful life of the container.

Experience gained in the manufacture of anhydrous hydrofluoric acid led to the production of purer grades of the aqueous acid and difficulties were encountered when this pure acid was stored in steel. In an attempt to explain the reason for failure of containers with the pure acid a series of experiments was made in which acid of various compositions was filled into drums and the behavior followed by means of recording pressure gauges and thermometers fitted into the drum closures.

It was almost immediately evident that pure hydrofluoric acid of 60 percent strength produced excessive pressure in the drums from the evolution of hydrogen even though the drum had been thoroughly passivated. It was found also that when the acid concentration was near 65 percent strength no pressure was produced in passivated or new unpassivated drums. Further experiments in which small amounts of sulfuric or hydrofluosilicic acid replaced part of the hydrofluoric acid indicated that within limits the acid produced no pressure provided that total water present was less than 36 percent.

It was apparent from these experiments that pure hydrofluoric acid of 60 percent concentration was unsafe when placed in steel containers. A set of experiments was made in which steel strips similar in composition to regular drum steel were placed in polyethylene containers and exposed to pure hydrofluoric % HF

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TABLE I Results of Exposing Steel Strips to Pure Hydrofluoric Acid

		WEIGHT		THICKNESS								
% HF	Start	Finish	Loss	Start	Finish	% Loss	IPY	Deposit				
58	14.6 16.1 14.7 14.8 15.3 16.3 14.5 18.6 15.3	9.8 12.0 11.4 12.5 15.1 16.2 14.4 18.5 15.2	4.8 4.1 3.3 2.3 0.2 0.1 0.1 0.1	.058 .059 .058 .058 .058 .058 .058 .056 .062	.052 .054 .054 .055 .058 .058 .056 .062 .058	32.9 25.5 22.4 15.5 1.3 0.6 0.7 0.5 0.7	.121 .009 .081 .059 .009 .0020 .0022 .0019	Thick Thick Thick Thick Slight Film Film Film				

acid of varying concentration. The steel strips (4 x ½ x 0.060 inches) were placed in bottles of acid of the concentration shown in Table I. The original acid used had an analysis of

$$HF - 69.9\%$$
 $H_2SO_4 - 0.12\%$ $H_2SiF_6 - 0.08\%$

and was diluted with distilled water to the strength shown in the table. Bottles were sealed to prevent loss of hydrofluoric acid and placed on the roof of a building and exposed to direct rays of the sun for

After exposure the steel strips were removed and cleaned with steel wool and weighed and measured. The type of deposit on each specimen was noted. The results are shown in Table I.

These results amply demonstrated that in the neighborhood of 64 percent strength there is a breaking point below which steel would be undesirable as a container for hydrofluoric acid.

The results obtained by short term tests where metal was exposed to hydrofluoric acid have not in a number of cases been too indicative of the life which could be expected of a given piece of equipment. In work at the writer's plant this discrepancy has been traced in several instances

to the loss of acidity from the solution by vaporization.

When dealing with anhydrous hydrofluoric acid difficulties were encountered as a result of the hygroscopic nature of the acid and it was possible to obtain high corrosion rates where as little as one percent of water was present.

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- tion, Bartlesville, Oklahoma (1946). 10. Meiklejohn, U. S. P. 1,553,321 (Sept. 25, 1925).

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in Corrosion, or who wish to register differences of opinion with respect to any articles are urged to send such discussions to Dr. F. N. Alquist, Chairman, NACE Editorial Review Committee, Organic Research Laboratories, 20A Building, Dow Chemical Co., Midland, Mich. Doctor Alquist will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make Corrosion more valuable to the membership.

Corrosion Problems in the Railroad Industry *

By RAY McBRIAN and L. C. ATCHISON

AS THE AUTHORS view it, "Preventing Corrosion of Railroad Materials" has been an important economic problem in which the railroads are constantly striving for solutions. The individual railroads, as users of metals in structures and equipment, are often faced with particular localized corrosion problems. The industry as a whole recognizes that the wide variety of operational conditions involving equipment traversing the entire country with widely variable climatic conditions, differences in loadings, handling, etc., presents an involved problem of corrosion.

The overall general trend for the solution of corrosion problems has been through the use of special corrosion resistant alloys, protective coatings, metal cladding, metal plating, cathodic protection, and in the use of chemical reagents to inactivate the corrosive media. Despite this general attack on the corrosion problems there remain in the railroad industry "corrosion cases" which are of great economic importance to it.

Possibly a review of some of the important problems which are recognized will better present the picture of the "Corrosion Problems in the Railroad Industry."

Passenger and Freight Cars

Railroad equipment corrosion problems as related to passenger and freight cars are important and it appears that the principal method of attacking these problems has been largely through the efforts of the suppliers of various types of alloys, who have stressed the advantages to be gained by using a special corrosion resisting material. Unfortunately, the results have not always equalled the claims because the basic knowledge and understanding of the problems, as applied to railroad equipment, was lacking in completeness. Some mechanical engineers fail to understand that there is no known economical material that will withstand all types of service conditions, and in this type of equipment corrosion the reasons that supposedly anti-corrosive materials fail is the failure to understand the conditions which arise. Some of these conditions are as follows:

Use of dissimilar metals as constructional members. Failure to make proper stress studies as to areas where high stress-corrosion can occur without proper protection or safeguards.

Failure to recognize that principles of proper venti-

Ray McBrian has been associated with the Denver and Rio Grande Western Railroad Company for twenty-five years. First employed as a chemist in 1925, he was promoted to Engineer of Tests and then to his present position of Engineers of Standards and Research. He attended the Colorado School of Mines and the Missouri School of Mines, graduating from the latter in 1924 with a B.S. in Metallurgy. He is presently a member of six technical societies.



L. C. Atchison graduated from the Colorado School of Mines as a Chemical Engineer in 1925. He subsequently was employed by the Missouri State Highway Commission, the Crystal Oil Refining Company and the Burford Oil Company until 1930. He then joined the West Texas Refining Company as Superintendent and in 1933 became Chief Chemist of the East Texas Refining Company. Prior to accepting his present position as Chief Chemist of the Denver and Rio Grande Western Railroad in 1937 he was General Manager of the Petroleum Processing Corporation.



Abstract

The problems from corrosion in the railroad industry are not of a specific type as may be found in other industries. This is because of the very variable and cyclic nature of the railroad operations, varying types of materials, climatic conditions, and service loadings. The subject will deal with some of the specific problems found with various types of motive power, track materials and passenger and freight cars. Entering into the railroad problem will be found such complex problems as of abrasion corrosion, vibration-velocity corrosion, wear as defined in terms of corrosion of Diesel locomotive wear surfaces, corrosion of so termed corrosion resistant materials and of problems specifically related to climatic conditions or as in territories where corrosion occurs from refrigerator car ice-brine drainage. The paper will discuss various solutions and results obtained. Specifically it will be found that the more serious corrosion problems in the railroad industry are "special ones" and that no general solution can be given. Each must be studied individually.

lation and removal of moisture from air is necessary.

Failure to recognize that most stainless steels owe their protection to the oxide film formed on the surface and that constant abrading from these conditions can result in rapid abrasion-corrosion.

Failure to properly evaluate particular materials for resistance to bulk loading materials.

*A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

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And another very important item is one of design which permits concentration of loading materials and solution in locations which can quickly result in corrosion problems.

Painting and coatings are largely a matter of experience and their application to prevent deterioration of material from corrosion is constantly being studied by the railroads.

Exterior Cleaning Problem

Mr. A. M. Johnson, Engineer of Tests, Pullman Company, stresses one important problem in this picture of corrosion directly related to the general exterior passenger car cleaning. Since various kinds of acids, compounds locally manufactured, or proprietary compounds are usually used in cleaning coaches, it can be appreciated that any undue acid concentrations or strongly caustic solutions can increase corrosion factors of cars made of aluminum, the various light weight and stainless steels, to such an extent that costly renewals may be required for framing members, sheets, etc.

Generally this type of corrosion is caused by these car cleaning materials seeping into the structural members and becoming absorbed in the insulating materials, thus forming a wet corrosive blanket or poultice against the metal surface. This can result in a very rapid rate of corrosion because drying cannot be accomplished. The use of mechanical car washers using various types of cleaners has greatly accelerated this type of corrosion because pressure sprays and fogs can easily enter through minute openings.

This is one type of important corrosion problem facing the railroads because many roads are now streamlining their passenger equipment and such expenditures require that all precautions must be taken to prevent early and costly maintenance repairs through this type of corrosion. This means that those railroads utilizing mechanical car cleaning equipment and cleaning compounds must thoroughly study this question of preventing corrosion through the development of properly inhibited materials, design features to eliminate pocketing of solutions, proper mechanical washing, rinsing and drying.

The Research Division of the Engineering Section of American railroads, is studying the corrosion of rail and fastenings, bridges, etc. by brine drippings from refrigerator cars. As reported in Bulletin 486, Proceedings of the American Railway Engineering Association, extensive laboratory tests were carried out, adding various types of inhibitors to brine solutions to determine their comparative effectiveness in minimizing corrosion of steel. The laboratory tests indicated that the use of sodium dichromate inhibitor buffered with soda ash should be effective in preventing corrosion of track and bridge structures due to brine drippings.

Service tests confirmed the laboratory tests. However, the problem has been further complicated by the necessity of adding the dichromate in such a manner as to avoid any possible contamination of the lading. This is requiring further research study and will be continued to a satisfactory solution by the Engineering Group of the AAR.

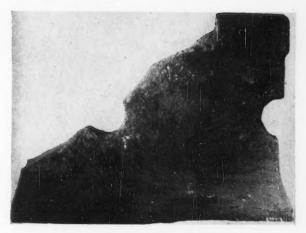


Figure 1—Corrosion-fatigue failure at rail end.

Rail Corrosion-Fatigue

The corrosion of rails which are buried or are in contact with soil at road crossings has been a subject of study to secure suitable coatings to prevent the development of corrosion-fatigue cracks. Typical example is shown in Figure 1.

A serious corrosion problem is that of the rail in the Denver and Rio Grande Western Railroad Company's Moffat Tunnel. This tunnel is 6.2 miles in length and the humidity is 100 percent. Diesel-electric locomotives and steam locomotives are used. The problem is one of corrosion-abrasion, each wheel removes the surface rusted layer and by the continuous cycle of corrosion, approximately ½ of an inch a year is lost off of the running surface of the rail. See Figure 2. No coatings can be used, stainless and similar materials which owe their protection to the formation of beneficial films would not be satisfactory. No solution for this type of corrosion problem—that is, corrosion-abrasion, has been found.

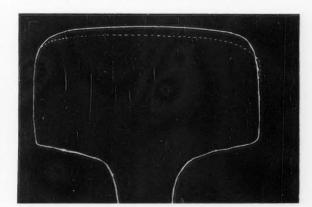


Figure 2—Corrosion wear pattern of rail from Moffat tunnel. Profilograph of 112-pound rail removed from mile post 52, December, 1939. Rail laid June, 1938. Dotted line shows amount of corrosion-abrasion wear. This amounts to .10 inches.

Another serious problem involving operational stresses is that of the formation of corrosion fatigue cracks in the fillet of rails in service on curves. Figure 3 is typical.

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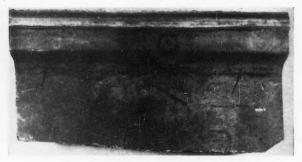


Figure 3

Studies of protection given by various types of coatings is producing some results. The problem has been partially solved by re-design of the rail to give a large fillet, thus reducing stresses.

The corrosion problem of rail fatigue cracks developing in joint bar areas, especially where rails have been packed with special inhibited fillers, is another problem requiring study. It appears this will require a means to reduce moisture in these areas to an absolute minimum, even to the point of eliminating condensation.

Problems of corrosion of structures in American railroads are being principally solved through proper application of proper coatings. Individual railroads are studying the newer types of coatings under various climatic and other conditions.

Water Inhibitors

Boiler and firebox corrosion of steam locomotives has been greatly reduced by research and development of water treatments. Despite this remarkable improvement through researches in the field of water treatment it was not in the cards for the steam locomotive to be economically competitive with the newer Diesel-electric power. This newer type of motive power which is so overwhelmingly replacing steam power on American railroads has opened up and is continually bringing forth new problems of corrosion which are requiring the attention of the railroad research investigators.

Jacket water problems in Diesel engines illustrate one of these newer corrosion problems. Serious damage may be caused by using a corrosive jacket cooling water. Some soluble mineral salts cause serious corrosion. Difficulty is experienced also when distilled water, water supplies with entrained air as typical of supplies pumped by air lifts, and waters high in carbon dioxide are used.

One of the most effective remedies has been that of treating the water supply with small amounts of chromate or bichromate. Railroads must constantly be on the alert for changes in constructional materials which can alter the results obtained by methods used for long periods and which were found to be satisfactory.

The problem of cavitation-erosion of Diesel liners, etc. has been most ably presented by Messrs. Speller and LaQue.¹ Another phase of this type of problem is now arising, as is shown in Figure 4, which illustrates this same general type of cavitation-erosion problem being found in fuel injection lines.

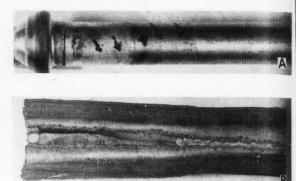
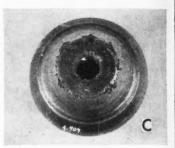


Figure 4—A—Split in tube at nozzle at arrow. B—Tube opened up to show cavitation erosion. C—Showing this same type of cavitation erosion of nozzle end of tube. The tube material is soft carbon steel, analysis: .08 to .13 percent carbon, .30 to .60 percent manganese.



This problem will have to be studied in the light of the work of Messrs. Speller and LaQue. No known fuel oil additive to date is available to overcome this condition. Fuel oil used was the best obtainable, sulfur content did not average above .20 percent.

The problem of corrosion is considered one of the principal causes of wear in internal combustion engines. With the railroads rapidly Dieselizing, it is their principal goal to secure the longest possible life of all working parts. This problem of corrosion in Diesel-electric locomotives then becomes one of major economic importance.

Lubricating Oil Studies

Therefore, the Denver and Rio Grande Western Railroad Company has become greatly interested in Diesel crankcase chemistry, and through the use of the spectrograph has been able to detect wear, corrosion, or whatever action this term indicates, in its earliest stages. The use of the spectrograph makes it possible, by analyzing an ashed sample of lubricating oil, to determine abnormal corrosion-wear without dismounting the engine. In this subject of corrosion-wear, it is desirable to distinguish between that occasioned by chemical attack of the metal and that resulting from the friction of metal on metal or abrasion.

In the majority of cases of wear-corrosion, the metals are present as oil soluble salts or organic complexes in the oil. In the case of abrasion wear, they remain in a metallic state in suspension. These suspended particles are usually removed and held on the filters and thus the ashed samples contain principally the additive compounds and the corrosion products.

Corrosion wear in Diesel engines can be followed by igniting samples of oil at specified mileages and noting sampl

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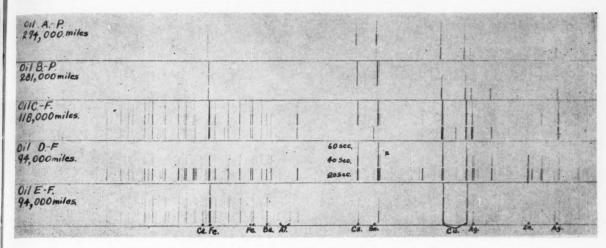


Figure 5—Metals present in this spectrograph are the result of corrosion, authors believe.

noting the development of color in the ash. The ash sample of new oil is cream colored, but as wear corrosion occurs the color changes to dark red.

Figure 5 is a typical spectrograph of different types of used oils at various mileages. The metals present have accumulated as corrosion products.

Oils must, therefore, have the proper base-stocks and additives to reduce this type of corrosion wear to a minimum.

There are other problems bordering in principle on that of corrosion or corrosion-abrasion other than the field of metals. The reason this is mentioned is that the solution of such problems must be obtained in the same manner as those used in solving similar problems. An example is Figure 6.

Figure 6-Deterioration of ties.

This wear is called tie abrasion. It is the result of moisture and grit, and the same cyclic wear as occurs in corrosion-abrasion. The solution is to coat the tie with a water-resistant coating or pad which resists abrasion and prevents wear.

It can be seen that corrosion problems in the railroad industry are of widely different natures and that no specific general solution is possible. Each must be studied separately. The railroads individually, and through the American Association of Railroads, are endeavoring to find these solutions through research.

Reference

 F. N. Speller and F. L. LaQue. Corrosion 6, 209-215 (1950).

DISCUSSION

By Marc Darrin, Mutual Chemical Company of America, 1348 Block Street, Baltimore 31, Maryland.

Mr. McBrian showed a very interesting colored slide illustrating the appearance of the ash from various used lubricating oils. One with a brown color was said to represent contamination with chromate. First I would like to ask how this happened to be present in the oil; and second, if due to leakage from the cooling water system, did it cause any serious difficulty, and was its presence associated with any particular type of diesel or operating conditions.

Authors' Reply:

Chromates are added to cooling water as rust inhibitors or corrosion inhibitors. Cooling water contamination in the crankcase oil accounted for the presence of the chromate. No serious difficulty has been encountered. Certain oils will reject chromate and deposit it on the lube oil filter. Others retain chromate and could conceivably result in some deposit or lacquering trouble if concentrations of chromate were high enough. The presence of chromate is not associated with any particular Diesel or type of operation. However, in Diesels where chrome plated liners, etc., are used it must be determined that water inhibitors are responsible.

The Influence of Stress on Corrosion*

By JULIUS J. HARWOOD*

(Continued from Corrosion, 6, No. 8, 249-59 [1950] Aug.)

Nature of Stress-corrosion

The acceleration of the rate of corrosion of metals by stress generally is accepted as the definition of stress-corrosion. The limiting situation, stress-corrosion cracking, is the spontaneous cracking which may result from the combined effect of stress and corrosive attack. The types of corrosion phenomena which are to be included under this generic term usually occur under conditions where the extent of general corrosion is slight; i.e., the corrosive medium produces an effect between the extremes of general corrosion and passivity, which results in severe localized attack when the additional influence of stress is present. The subject of corrosion fatigue which also involves the conjoint action of cyclic or repeated stresses and corrosive attack is closely related, and is important enough to warrant separate treatment. The influence of environment upon the creep of metals is rapidly being recognized and constitutes another related field in which corrosive influences and stress are acting in a cooperative manner to accelerate failure; or interestingly enough under certain conditions to reduce failure since, for example, the creep rate of cadmium is less in certain solutions of cadmium salts than in others.41

Stress-corrosion is a most insidious type of attack and failure may be sudden and rapid, often occurring without prior warning. Localized corrosion attack, resulting from the presence of anodic zones developing from composition or strain gradients or from local breakdown of protective corrosion films, develops pits or trenches. Regions of stress concentration favorable to the initiation of cracks are thus formed. Under the combined action of stress and corrosion, these cracks are propagated. Although the earliest record of stress-corrosion can be traced back to 1886 when Robert-Austen reported the cracking of a gold-copper-silver alloy in ferric chloride 42 the exact mechanisms of stress-corrosion in most metal systems still are not understood well. The mystery which still surrounds the "season-cracking" of brass and the stress-corrosion of magnesium alloys are but two examples of the lack of knowledge about the manner in which these cracks are generated and propagated. However, the factors involved in stresscorrosion attack are clearly recognized and their influence has been studied extensively. Thus, while the

mechanisms of the attack are still obscure, satisfactory methods for the prevention and elimination of stress-corrosion in many specific systems have been Septemb

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The principal factors involved are stress, environment, composition, internal structure and time. Stress corrosion has no respect for composition. There is hardly a structural metal system known which does not contain some alloy composition susceptible to stress-corrosion cracking. Brass, steels, stainless steel, aluminum and magnesium alloys, lead, nickel alloys all have been shown to be susceptible in the proper environment. Indeed, it has been stated that solutions probably can be found to stress-corrosion crack any known metal or alloy. Table I lists several of the commercial metals and alloys and the environments in which stress corrosion will occur. It is only fair to state, however, that despite abundant literature on the subject, the development of preventive methods has reduced the occurrence of stress-corrosion cracking of industrial alloys to the extent it is not a major source of service failure. But, the inability, in many cases, to predict the degree to which stress corrosion may be expected and the magnitude of the failure, when failure does result, make it important to gain a more thorough understanding of the process. In addition, it may be anticipated that the increasing use of higher operating stresses will result in a greater frequency of service failure from stress corrosion. The stresses responsible for accelerated corrosion usually are residual or a combination

TABLE I—Alloy systems and some reported stress-corrosion environments

Alloy System	Environments
Aluminum Base Alloys	NaCl—H ₂ O ₂ solutions NaCl solutions Sea water Air, Water vapor
Copper Base Alloys	Ammonia Vapors and Solutions Amines
Magnesium Base Alloys	NaCl—K ₂ CrO ₄ Rural and coastal atmospheres Distilled water
Mild Steels	NaOH—Na2SiO3 solutions (caustic embrittle ment) Nitrate solutions (calcium, ammonium and so dium nitrate) Aqueous solutions of HCN
Stainless Steels	Acid Chloride solutions NaCl—H ₂ O ₂ solutions Sea water H ₂ S
Nickel. Monel	Caustic Soda solutions Fused caustic soda Hydrofluoric acid Hydro fluosilicic acid (H ₂ Si F ₆) Steam Caustic soda solutions
Lead Gold-Copper-Silver Alloys	Lead Acetate solutions FeCl3 solutions Acetic acid-salt solutions

^{*}A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

*Acting head, Metallurgy Section, Office of Navai Research, Department of the Navy, Washington, D. C.

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of residual and operating stresses induced by service loads. General experience has demonstrated that tensile stresses of considerable magnitude are necessary for stress corrosion to occur. There have been no instances reported, either in laboratory tests or under service conditions, in which stress-corrosion has been

STOPPER TUBE BREAK LIQUID LEVEL STOPPER

Figure 19—Typical failure of brass tensile specimen in ammoniacal atmosphere — fracture perpendicular to direction of tensile stress.

(Morris.44)



Figure 20—Forty-five degrees cracking in brass tube subjected to torsional stress in ammoniacal atmosphere. (Morris. 4)

attributed to the action of compressive stress. A common type of laboratory test for the study of stress corrosion employs a test specimen sprung in the form of an arc or loaded as a simple beam. Such tests have shown conclusively that stress corrosion always is initiated at the surface which is in tension and never on the compression side. Indeed, this has led to the use of surface compressive stresses, such as those produced by shot peening, as a method of prevention against stress-corrosion cracking.

Stress-corrosion cracks generally proceed in a plane perpendicular to the direction of the highest tensile stress.⁴³ Thus in test specimens subjected to axial tensile loading, failure is normal to the axis of the bar, Figure 19, whereas in a specimen which is stressed in torsion, failure occurs at an angle of 45° to the long axis of the bar, a plane perpendicular to the plane of maximum shear stress, Figure 20. In tubes containing both residual circumferential and longitudinal stresses, as a result of fabrication, maximum stress would be the resultant of the two and cracks therefore would assume some angle to the tube axis. Cross cracking occurs only when the stress

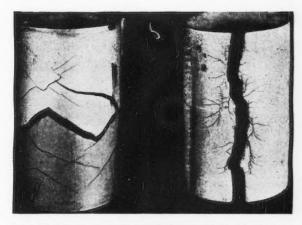


Figure 21—Stress cracks produced by high longitudinal and hoop stresses in cold drawn Types 347 and 316 stainless steel tubing. Tested in MgCl₂ solution boiling at 309° F. (Scheil—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)

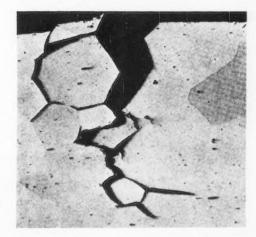


Figure 22—Intergranular stress-corrosion cracking in brass exposed to ammoniacal atmospheres. X 20 approx. (Perryman—Institute of Metals monograph "Symposium on Internal Stress in Metals and Alloys," 1948.)

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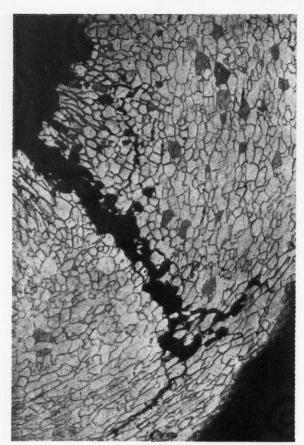


Figure 23—Intergranular stress corrosion cracking in thin mild-steel plate exposed to ammonium nitrate at atmospheric temperature, X 100 approx. (Heeley—Institute of Metals monograph, "Symposium on Internal Stress in Metals and Alloys," 1948.)

is almost entirely longitudinal, as illustrated by the left-hand tube of Figure 21, and longitudinal cracking results when the stresses are predominantly circumferential as shown by the right-hand tube in the same figure. In many cases, however, grain elongation and orientation influence the direction in which the cracks proceed.

Internally, stress corrosion cracks may be either intergranular or transgranular, depending upon the composition of the alloy and the corrosive environment. Alpha brass in ammoniacal atmospheres, aluminum alloys in chloride solutions and mild steel in nitrate solutions predominantly exhibit intergranular cracking, Figures 22, 23. On the other hand, stainless steels in acid chloride solutions, β brasses and magnesium alloys almost invariably crack in a transgranular manner, Figures 24, 25. Note that, by the mere change of the pH of the solution, the path of failure of a magnesium alloy was changed from a transgranular one to an intergranular one. Compare Figures 25, 26.

As the applied load or internal stress increases, the greater is the acceleration of corrosion and the rate of cracking. This can be demonstrated, for example by Morris' data for brass⁴⁴ shown in Figure 27 and some test results on magnesium alloys shown in

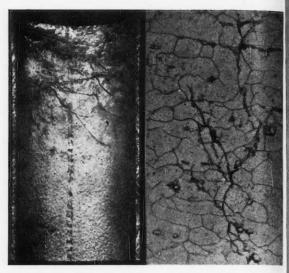


Figure 24—Stress corrosion cracks in austenitic stainless steel tube.

Photomicrograph shows transgranular nature of cracks. Tube left ¼ size. Right: X 800. (Keating. 45)



Figure 25—A stress-corrosion crack produced in AM-C57S sheet exposed to a solution containing 35 g of sodium chloride and 20 g of potassium chromate (pH 8.1) per liter. X 500. Note that the path of the attack is largely through grains and does not appear to have any relation to the microstructure. (Mears, Brown and Dix.²⁴)

Figure 28. Similar curves can be shown for most alloy systems exhibiting susceptibility. It is interesting to observe in the experiments of Morris that quenching so increased the resistance of naval brass, as compared to air cooling, that higher stresses were re-

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Figure 26—A stress-corrosion crack produced in AM-C57S sheet exposed to a solution containing 35 g of sodium chloride and 20 g of potassium dichromate (pH 5) per liter. X 500. Note that the path of the attack tends to follow an intergranular path or proceeds along the slip planes. (Mears, Brown and Dix. 24)

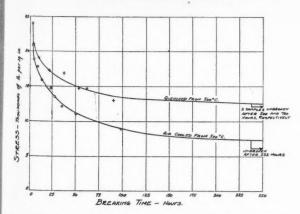


Figure 27—Effect of stress on time to stress corrosion failure of brasses in ammoniacal atmosphere. (Morris.⁴⁴)

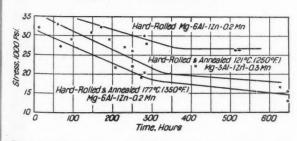


Figure 28—Effect of stress on time to failure of magnesium alloys in 3 percent NaCl. (Loose—"Magnesium," ASM, 1946.)

quired to produce stress-corossion cracking. Usually stresses, approximately equal to the yield strength, are required to cause stress-corrosion cracking, although frequently stresses of quite low magnitude are sufficient. Numerous investigators have attempted to ascertain "threshold stresses"; i.e., the maximum stress which an alloy will sustain without failure by cracking in a suitable corrosive environment, but the results have been quite erratic even for the same alloy. This may be due to several factors. Keating⁴⁵ pointed out that in the initiation period of attack stress concentration pits will vary in dimensions and within the limits of variation considerable differences in stress concentration factor may be produced, as indicated in Figure 29. With variations of this order in the stress concentration factor, it is not surprising, therefore, that erratic results for threshold stresses have been reported. In addition, incomplete knowledge about the residual stresses which may be present, particularly in cold worked metals, confuses the determination of the value of the actual effective stress that is operative. Finally there is the situation, as discussed earlier, where the actual yield point is considerably less than conventional tests indicate. Thus, under favorably oriented conditions, localized plastic flow may occur under rather low stresses and provide local areas for crack propagation.

THE INFLUENCE OF STRESS ON CORROSION-PART II

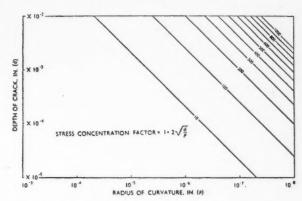


Figure 29—Variation of stress concentration factor with depth of crack and radius of curvature of root and crack. (Keating. 45)

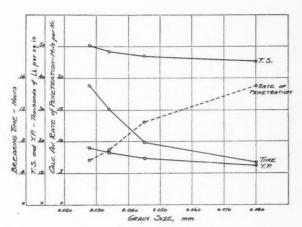


Figure 30—Effect of grain size on time to failure, (Morris.44)

Environmental factors will be discussed in greater detail in the

following sections, but it is signifi-

cant to point out here that in many instances the remarkable specificity of certain corrosive environments in producing stress-corrosion has hindered somewhat the development of a universal mechanism of stress-corrosion. The chemical conditions which produce cracking in the presence of stress are strikingly individual to each alloy system. As mentioned previously, corrosive environments which are generally most conducive to stress corrosion cracking are those which produce relatively mild surface corrosion but highly localized attack. Changes in type of cracking or in the degree of susceptibility to stress-corrosion by changes in the environment may result from: 1)

changes in the relative potential of

the structural phases present in the alloy, 2) anodic or cathodic polarization, 3) increase in corrosion rate of the parent matrix (increase in

The time required for complete stress corrosion failure may vary from several minutes to years, depending of course upon the degree of stress, corrosive environment and other factors. To indicate some comparison as to rates of corrosion, the speed of stress-corrosion crack-

general corrosion).

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Figure 31—Direct-load units used in laboratory testing. (Loose and Barbian—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)

ing in aluminum alloys has been reported to be 0.01 mm/min., while the velocity of intergranular corrosion is approximately 0.01 mm/day. 46 In some alloys, internal reactions which occur upon aging render the material more susceptible to stress-corrosion attack as time goes on. As will be seen later, stress may play a fundamental role in "triggering" or accelerating the rate of these transformations. Also, long times may be required before corrosion proceeds to the extent necessary for the rapid acceleration process to begin.

The internal structure is of great importance in stress-corrosion. Variations in composition, fabrication and thermal treatments have a decided influence upon the microstructure and consequently upon the stress-corrosion susceptibility. The role of microstructure will be elaborated upon in the next sections, but a brief idea of its importance is provided by Figure 30, which illustrates the effect of increasing grain size on lowering the resistance of brass to stress-corrosion attack on ammonia. Small variations in composition may also produce significant differences in the stress-corrosion susceptibility of several metal systems, without any apparent effect on the internal structure. For example, less than 0.2 percent of phosphorus, antimony or arsenic is sufficient to

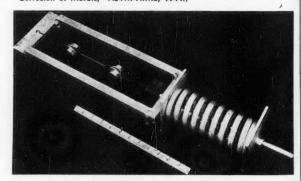


Figure 32—Spring-load testing unit. (Loose and Barbian—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)

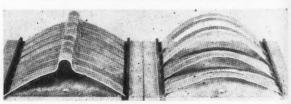


Figure 33—Fixtures for stress corrosion test at constant deflection. (Sager, Brown and Mears—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)

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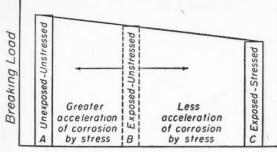
make copper readily susceptible to stress-corrosion in ammoniacal atmospheres.⁴⁷ On the other hand, the addition of chromium of about 0.3 percent to the

Figure 34—(Top) Fixture for testing a cantilever specimen uniformly stressed in given gage length. (Franks, Binder and Brown—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)



Figure 35—(Right) Eccentric load testing unit. (Loose and Barbian— "Symposium on Stress Corrosion of Metals,"ASTM-AIME, 1944.)

tals.



Stressed specimen does not break.

Figure 36—Influence of stress and exposure on rate of corrosion. (Dix and Brown.⁴⁹)

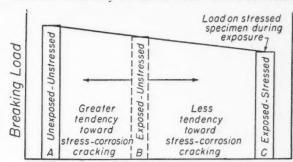
high strength 75S wrought aluminum alloy inhibits stress-corrosion susceptibility.⁴⁸

Test Methods

Since the evaluation of susceptibility of stresscorrosion cracking of structural alloys under simulated service conditions generally requires long exposure times under conditions in which the actual operative state of stress is uncertain, accelerated laboratory and exposure tests often are necessary. Test specimens and test methods in which the magnitude and state of stress can be determined with reasonable accuracy and test solutions which produce failure in reasonable periods of time are employed. While these accelerated laboratory tests often are quite severe and not representative of service conditions, and in many cases do not correlate too satisfactorily with service experience, they furnish valuable information concerning the stress-corrosion behavior of alloys. These tests are widely used for control purposes, development and selection of alloys with superior stress-corrosion properties, and provide some measure of the limits which a given alloy can satisfactorily withstand. They are, of course, invaluable for research purposes to study the mechanisms of stress-corrosion cracking.

Generally, two types of specimens are employed. Either tensile specimens, which are externally loaded (dead weight or otherwise), or beam type specimens, which are bent to constant deflection or under constant loads, are most frequently used. By measuring the deflection in the beam specimens the outer tensile stresses can be calculated by conventional beam formulae. These types of specimens also provide information about the influence of compressive stresses, because the concave side of the specimen is under compression. Typical examples of these test specimens and methods are illustrated in Figures 31-35. The tests are sometimes conducted in natural environments, such as atmospheric exposure or sea water immersion, but most generally laboratory test media are used. Under laboratory conditions, continuous immersion, partial immersion, intermittent immersion, and spray type tests are used. The type of test specimen and solution will, of course, vary with the alloy system and the type of information desired.

In evaluating results of such accelerated laboratory tests, it sometimes becomes important to differentiate between what may be called "true" stress-corrosion



Stressed specimen breaks during exposure.

Figure 37—Influence of stress and exposure on tendency toward stress corrosion cracking. (Dix and Brown. 49)

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and the acceleration of corrosion by stress. The latter may cause failure by the reduction of the load supporting area resulting from the corrosion reactions, whereas the former results in a spontaneous cracking type of fracture. The ASM Metals Handbook⁴⁹ describes a method by which these two cases may be differentiated. Suppose three identical tensile test specimens are employed, one of which serves as an unstressed unexposed blank (Specimen A); the second which is exposed to the corrosive environment in the unstressed condition (Specimen B); and the third which is stressed under constant load and exposed to the same corrosive environment (Specimen C). If, as in Figure 36, the stressed specimen does not break during the life of the test, then Specimens B and C are subsequently loaded to failure. The breaking load of Specimen B, as related to the breaking load of Specimens A and C, show the extent of the accelerating effect of stress on the rate of corrosion of corrosion of Specimen C. The closer the breaking load of B to that of C, the less has been the acceleration of corrosion by stress; and the closer the breaking load of B to that of A, the greater the acceleration of corrosion by stress. If, on the other hand, Specimen C breaks under the combined action of stress and corrosion, then, as shown in Figure 37, the closer the breaking load for Specimen B to the load on Specimen C during exposure, the less the tendency toward stress-corrosion cracking. Thus, failure of C may have been due to a reduction of the cross sectional area by corrosion such that the specimen could no longer support the applied load. But the closer the breaking load of B to that of the control sample A, the greater the tendency toward stresscorrosion cracking of Specimen C. It is recognized that it is often difficult to distinguish clearly between stress-corrosion cracking and the acceleration of corrosion by stress. Some may consider the differentiation between the two as only a matter of degree, but it bears a definite implication concerning the function of stress in the stress-corrosion reaction. In one case, the localized corrosion (e.g. intergranular corrosion of sensitized 18-8 stainless steel or aluminum-copper alloys) occurs even in the absence of stress, though not at so rapid a rate, whereas for the other situation, the corrosion attack may be insignificant in the absence of stress.

Theories of Stress-Corrosion

Early theories of stress-corrosion ascribed stress-corrosion cracking either to simple chemical corrosion or to mechanical failure as a result of high internal stresses. Both of these were obviously inadequate, ignoring either the importance of the stress factor or the environmental factor. Another theory which received wide attention was based on the hypothesis that intercrystalline stress-corrosion cracking was due to the presence of an amorphous intercrystalline material which differed in character from the crystals themselves and had a higher chemical reactivity. It is now well recognized that where the failure is due to the combined action of stress and corrosion, an electrochemical mechanism of stress-corrosion is operative. But, while general agreement

has been achieved concerning the initial stages of the reaction, disagreement still exists as to the true function of stress and the function of the corrosive environment subsequent to initiation of attack.

Electrochemical Theory

As a result of their experiments on the acceleration of corrosion of aluminum alloys by high constant stresses, Dix and his associates 50, 51 proposed an electrochemical theory of stress-corrosion cracking. Dix pointed out that, in order for acceleration of corrosion by constant stress to occur, two conditions must prevail: 1) there must exist in the alloy a susceptibility to selective corrosion along more or less continuous paths, and 2) there must exist a condition of high stress acting in a direction tending to pull the metal apart along these continuous paths. The continuous, localized paths may consist of grain boundary areas which are anodic with respect to the bulk of the grain. This condition may be brought about by selective precipitation at the grain boundaries, when either the precipitated phase is anodic to the solid solution matrix or when the depletion of the solid solution zones of the alloying element along the grain boundaries, as a result of precipitation, makes these impoverished areas anodic to the richer solid solution within the grains. Thus, a galvanic cell is established consisting of a large cathode and small anode, and the current flow from these anodic zones along the grain boundary results in concentrated and accelerated corrosion in these zones. In the presence of stress, as the preferential intense attack progress, a high stress concentration will develop at the root of the corroding path. The deeper the attack and the smaller the radius, the greater the stress concentration. At sufficiently high stress, the metal will start to tear apart, and fresh film-free metal will be exposed to the action of the corrosion environment. This freshly exposed metal is anodic to the film covered matrix, thus maintaining the electrochemical action and causing an acceleration of corrosion. Further corrosion results in further tearing of the metal and the cooperative action of corrosive environment and tensile stress increases the rate of penetration until the metal fails. As shown previously, the greater the stress, the greater the acceleration of corrosion. It is important to note that the electrochemical theory of stress corrosion, first proposed in this country by Dix and his associates, in addition to requiring the obvious presence of both tensile stress and corrosive environment is based upon the following two points: a) that the internal structure of the metal be such that a susceptibility to localized corrosion exists in the particular corrosive environment (the localized path being the anodic area and the matrix comprising the cathodic area); and b) that the function of stress is to open up these corrosion crevices and expose fresh anodic material to the corrosive medium.

The existence of these localized anodic zones at the grain boundaries has been beautifully demonstrated by Brown who used some elegant techniques of measuring electrode potentials in localized areas. One of the techniques used was to paint out either the grain boundaries or grain bodies of large grained

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Figure 38—Schematic illustration of the microstructure of a wrought Al-Cu alloy containing 4 percent Cu. A uniform solid solution has been retained after rapid quenching from the temperature of solution heat treatment. The electrode potentials of grains and grain boundaries are equal, (Dix and Brown.⁴⁹)

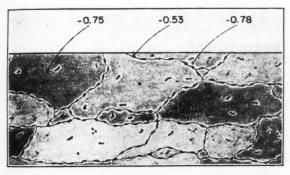
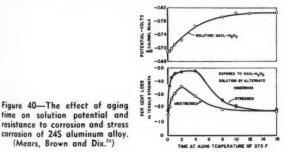


Figure 39—Same alloy as Figure 38 after a period of reheating that caused difference of potential between grains and grain boundary regions. (Dix and Brown. 49)

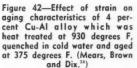


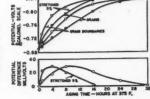
-0.84 -0.53 -0.84

(Mears, Brown and Dix.34)

Figure 41—Same alloy as Figure 8 after long period of reheating. Nearly complete precipitation has caused equipotentialization between grain bodies and grain boundary zones. Both are anodic to particles of precipitate. (Dix and Brown. 49)

specimens with an insulating water-impervious coating, so that, when the specimen is immersed in an electrolyte, either the grain bodies or a zone about 1 mm. wide along the grain boundaries is exposed. In an aluminum-4 percent copper alloy (a system which was intensively studied), precipitation at elevated temperatures, after solution heat treatment, caused the depleted zones adjacent to the grain boundaries to be as much as 0.044v more anodic than the grain boundaries. Refined techniques, making use of a capillary tip to determine the potential of an extremely small area, indicated that the potential difference between the grain boundaries and bodies may be as much as 0.2v. These conditions are shown schematically in Figures 38, 39. A similar situation exists in stainless steels, in which the preferential precipitation of chromium carbides along the grain boundaries, resulting in the depletion of chromium content of the solid solution along these boundaries, makes the grain boundaries anodic to the main grain bodies. Because aging at sufficiently high temperatures for sufficiently long periods causes general (homogeneous) precipitation to occur, i.e. precipitation in the grain bodies as well as at the grain boundaries, it should be expected that equipotentialization should result with no susceptibility to stress-corrosion. Figure 40 illustrates that this is what happens. After about 11 hours of aging time at 375° F, almost complete decomposition of the solid solution occurs, and the overall potential approaches that of aluminum itself. When this occurs, no difference of potential between the grain boundaries and grain bodies exist, Figure 41, and no preferential attack along the grain boundaries occurs. Naturallyaged Al-Cu alloys, which do not undergo visible precipitation at the grain boundaries and do not, therefore, contain selective anodic paths for electrochemical corrosion, are not particularly susceptible to stresscorrosion.





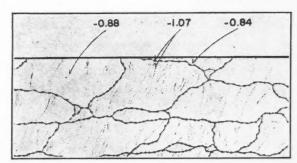


Figure 43—Schematic illustration of microstructure of a cold-rolled AI-Mg alloy containing 10 percent Mg. Continuous zones of anodic particles of precipitate occur on grain boundaries and slip planes. (Dix

Cold working of the alloy or the presence of stresses will accelerate the precipitation both in the grain boundary zones and in the grain bodies as demonstrated in Figure 42. Plastic deformation will also result in precipitation along slip planes, thus introducing other paths for localized corrosion. In addition, in some alloy systems, which ordinarily would not exhibit a precipitation reaction, stress may cause localized precipitation to occur, e.g. strain aging of steels. This implies another role of stress in the stress-corrosion reaction which will be discussed shortly.

In the aluminum-magnesium alloy system, the precipitated constituent is the compound Mg, Al, which, in neutral chloride solutions, is anodic to both the grain body and the depleted zone along the grain boundary. (Figure 43.) If the precipitation treatment is such that a continuous network of this Al-Mg constituent is developed then stress-corrosion cracking of the alloy can be expected. In chloride solutions containing NaOH, it has been shown⁵¹ that the precipitate Mg₅ Al₈ is cathodic to the main solid solution; thus stress-corrosion cracking should not be expected in alkaline solutions. Specimens of a 10 percent Al-Mg alloy, aged so as to be susceptible to stress-corrosion cracking, when tested in NaCl-H₂O₂ solutions failed in 15 minutes, whereas with the addition of NaOH to the test solution, no susceptibility to stress-corrosion attack was observed. This provides strong confirmation of the electrochemical theory of stress-corrosion.

Thus, in alloys exhibiting tendencies to stress-corrosion cracking because of precipitation at grain boundaries, the electrochemical characteristics of three different areas require consideration:

- A) the central portion of the grain (solid solution matrix)
- B) the precipitated phase at the grain boundaryC) the solid solution zone along the grain boundary which undergoes a change in composition.

The electrode potentials of these three areas, as just illustrated, will depend upon the corroding environment. If C) is anodic to both A) and B), intense intergranular attack will occur because of the large cathode to anode ratio. If the large area A) shares the anodic attack with C), the attack will be of a general character, and no localized attack at the grain boundaries need be anticipated. If B) is anodic to A) and C), intergranular attack will only occur if a continuous network of the anodic constituent exists. Akimow⁵² has postulated that the addition of sufficient amounts of alloying elements, which shifts the potential of zone A) in a more anodic direction, even if it makes zone C) correspondingly more anodic, will alter the intergranular attack into general corrosion.

There is additional evidence which tends to establish the validity of the electrochemical mechanism of stress-corrosion. Using the same techniques described above, Mears et al⁵¹ found that the grain boundary zones of large-grained annealed brass were anodic to the grain bodies by about 0.072v in aqueous ammonium solutions. If the solutions were more concentrated, the potential difference was even larger. The change in mode of cracking of a magnesium base

alloy (6.5 percent Al, 1 percent Zn) from transgranular to intergranular cracking with change in pH of the solution, previously illustrated in Figures 25, 26, indicates a change in the electrochemical characteristics of the three zones. One of the strongest supports for the electrochemical mechanism has been the demonstration^{51, 53} that stress-corrosion failure can be prevented by the application of the principles of cathodic protection. Magnesium base alloys, brass, stainless steel and mild steel all have been experimentally cathodically protected against stress-corrosion cracking by the application of impressed currents or by coupling to external anodes.

Film Theories of Stress Corrosion

The localized paths for the initiation of corrosion, in addition to being caused by composition differences, also may be the result of local breakdown of protective corrosion films under the influence of either stress or corrosion environment. As discussed previously, this factor constitutes an essential part of the electrochemical theory for the maintenance of the stress-corrosion reaction. It has been postulated⁵⁴ that the film at grain boundaries is less protective than over the crystal faces because of the irregular distribution of atoms resulting in an irregular film pattern. Under the influence of stress, these films are more easily broken and corrosion can proceed. Champion⁵⁵ is of the opinion that the real effect of stress-corrosion in aluminum alloys comes toward the end of failure and is bound up with film formation. He suggests that, as intercrystalline corrosion proceeds, a sufficiently high stress concentration at the bottom of the crack may be reached which will cause plastic deformation of the metal. This results in cracking of the film and the continuation of corrosion by the formation of a filmed metal-film free metal cell. If new film formation can stop the corrosion before a dangerous stress concentration is again reached, then rapid crack propagation will be prevented. But, if the necessary stress concentration is reached before corrosion is stopped by the film formation, the cycle of plastic flow of the metal and film rupture reoccurs causing early failure of the metal by stress-corrosion. This viewpoint indicates that susceptibility to stress corrosion is dependent upon film-forming properties and deformability of the metal and implies that stress plays no direct part in crack propagation.

Although some recent British work has emphasized the importance of the oxide film factor in the stress corrosion of A1-Cu alloys, generalized extension of film based theories are questionable, because under certain conditions it is doubtful whether film formation occurs. In addition, the theory requires preferred corrosion paths and is not applicable to alloys which fail by transgranular cracking, e.g., Mg alloys, stainless steel, beta brass, etc. The theory also does not account for the changes in mode of cracking by the application of stress or change of environment as has been previously illustrated.

Mechanical Theory of Stress Corrosion

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THE INFLUENCE OF STRESS ON CORROSION-PART II

of stress in the stress-corrosion mechanism is confined to the development of purely mechanical damage, i.e., tearing open the metal underlying the surface crevice and propagating the crack. While he is in agreement with the electrochemical mechanism for the initiation of corrosion, he does not believe that corrosion plays an active part in crack propagation. Thus, according to Keating, as soon as crevices produced by localized corrosion achieve critical dimensions, stress concentrations open them into fine cracks. Crack propagation proceeds this way until the advancing crack front encounters an obstacle which reduces the stress concentration to a level below that necessary for the procession of the crack. Such obstacles may be non-metallic inclusions, lattice discontinuities, or unfavorably oriented grain boundaries. While the crack propagation is arrested, awaiting diffusion of the corroding medium to the tip of the crack, lateral corrosion may occur along the anodic material on the sides of the crack, which may explain the branching nature of many stresscorrosion cracks. When the active corrodent reaches the point of the crack, attack will produce fresh points of stress concentration which may, in the case of intergranular attack, be a more favorably oriented grain boundary. It is possible that this mechanism may account for the partly transgranular and partly intergranular cracks which occur in several alloys.

It would appear that support for a mechanical theory of stress-corrosion should be found in an examination of the crack or fracture surfaces, if techniques can be developed to stop the process before corrosion alters the fractured surface too drastically. Under the conditions of crack propagation required by the theory, the geometry of the situation would indicate no significant deformation, and, therefore, a nonductile type of failure might be expected. Under such conditions of restraint, (e.g., presence of notches or high strain rates,) body centered cubic metals, such as iron and mild steel, fracture along well-defined crystallographic (cleavage) planes. For face centered cubic metals, such as alpha brass and aluminum, the path of failure would be along slip planes. It is difficult, therefore, to account for the predominance of intergranular cracking in so many instances solely by mechanical forces. It seems more probable in those cases in which stress-corrosion proceeds intergranularly that some aspect of the corrosion process must account for the intergranular "weakness"; because at the temperatures involved (which are below the "equicohesive" temperature*) grain boundaries have been shown to be more resistant to flow and fracture than the grain interiors.

Strain Accelerated Decomposition Theory

The electrochemical theories of stress-corrosion described above are fundamentally based upon the pre-existence of a metallurgical condition which renders the material susceptible to stress accelerated corrosion. They are usually applicable to multi-phase alloy systems. But they suffer from the deficiency of not being able to explain adequately the stress-

Equicohesive temperature is defined as temperature above which fracture occurs intergranularly.

corrosion of homogeneous alloys, such as alpha brass or stainless steel, in which no serious susceptibility to corrosion exists in the absence of stress, and also in not being able to account for transgranular cracking in many alloys. One notable situation is the transgranular cracking of 18-8 stainless steels in acid chloride solutions, even when the alloy is in the sensitized state which would normally cause intergranular cracking in the absence of stress. In an attempt to overcome these weaknesses, Waber⁵⁶ has extended the "depleted zone" electrochemical theory to involve a strain accelerated decomposition of a metastable phase. In his "Generalized Theory of Stress Corrosion," one of the major functions of stress is to generate precipitation reactions, phase transformations, and order-disorder reactions which can provide the necessary localized anodic paths for corrosion. In those cases where the susceptibility to localized corrosion pre-exists, the theory reduces to a close similarity with the electrochemical theory proposed by Dix and his associates. Waber postulates that incipient cracks form from surface inhomogeneities and that, once formed, they continue to grow by the following mechanism. As a result of the stress-concentration at the apex of the crack, the metastable parent phase is decomposed faster in this vicinity than in the bulk of the metal. One of the decomposition products is anodic to the parent matrix and is corroded away by the medium. As a consequence, the crack grows, forming new anodic material ahead of it in its path, i.e., high local straining due to the presence of cracks accelerates the formation of galvanic microcells by the dissolution of the newly formed anodic phase.

In order for an alloy to stress corrode by this mechanism, Waber has postulated that the following minimum requirements must be satisfied:

- 1) The composition of the alloy must be such that a phase transition occurs on heating above room temperature.
- 2) The phase transition on cooling must be sufficiently sluggish that the high temperature phase can persist at room temperature.
- 3) This metastable phase must be capable of isothermal decomposition under the influence of stress.
- 4) The stress necessary to accomplish sufficient local straining to accelerate the decomposition of the parent phase should be considerably lower than the tensile strength.
- 5) At least one of the decomposition product phases, if there be two, must be anodic to the parent matrix.
- 6) Any corrosion products must be sufficiently permeable to the corrosion medium to permit diffusion of the reactant ions into the immediate vicinity of the crack apex, in order to prevent anodic polarization.
- 7) The corrosion rate must be higher at the apex of the crack than it is for the isolated parent matrix.

The relationship of these factors is summarized in Figure 44.

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As Waber points out, this decomposition theory of stress corrosion is predicated on the assumption that strain will accelerate the decomposition reaction of a single "apparently homogeneous" solid phase. These reactions may be of two types; one in which a single reaction product is produced, e.g., the strain decomposition of austenite into martensite or into ferrite; or a reaction in which two reaction products are formed such as in precipitation reactions in which the precipitate and the adjacent depleted solid solution zone represent the two products.

In any reaction which occurs spontaneously, thermodynamics dictates that there be a decrease in free energy. To state it another way, the reaction products must be more stable relative to the reactants, thus implying a more noble electrode potential. Waber has given a thermodynamic treatment of his strain acceleration theory and has recognized that a possible stumbling block to the satisfactory theoretical development is the necessity for the production of an anodic product from the reaction in order to satisfy the requirements of the electrochemical mechanism of stress-corrosion. Thermodynamically, it may be shown that the decomposition products must be cathodic to the parent matrix. He attempts to overcome such an objectionable feature by either postulating that the reaction proceeds through a transition stage in which the transient state is anodic to the matrix or that though the composite potential must be cathodic to the parent matrix, one of the decomposition products is anodic to the matrix. Thus, for a precipitation type reaction, the depleted zone can be anodic (e.g., Cu-Al alloys) or where both the depleted zone and precipitate are cathodic, the transition state of aggregation (Guinier-Preston zones) prior to microscopic precipitation produces a transient anodic phase. For single phase reactions, such as the decomposition of austenite, martensite is considered to be the transition phase, or in the case of alpha brass an order-disorder reaction is proposed as the responsible influence.

While the thermodynamic reasoning upon which the theory is based may be open to question, there is no doubt that the theory has significantly emphasized another possible function of stress, a function which is well supported by much experimental evidence. It has been abundantly demonstrated that cold work or stress accelerates decomposition reactions. In the case of precipitation reactions, the speed of the aging process is almost invariably increased by cold work after the solution heat-treatment, and precipitation may also occur during the straining reaction. Bainite formation in steels is accelerated by cold work, and the transformation of austenite to martensite is promoted under the influence of strain. Time and space do not permit a detailed analysis of the Waber theory, for this would require a discussion of the theory in terms of mechanisms of stress corrosion of the various alloy systems to which it has been applied. For stress-corrosion of precipitation systems, the theory only differs from the "depleted zone" theory in the explanation of crack propagation. Whereas the mechanism proposed by Dix and his

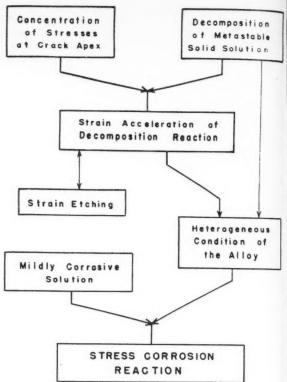


Figure 44—Relation of factors contributing to stress corrosion. (Waber.**)

associates postulates film rupture at the root of the crack, with the filmed matrix-film free metal cell sustaining electromechanical corrosion, Waber feels that the anodic phase produced by the strain-accelerated decomposition reaction is the basis of the electrochemical reaction. For the stress-corrosion of stainless steels, he proposes the transformation of austenite into martensite as the supporting mechanism. Martensite is considered the transition product and thus is proposed as the anodic phase. This classification of martensite seems highly speculative, because the martensite thus produced can be quite stable relative to the austenite. The application of this mechanism to the stress-corrosion of stainless steels is now under experimental investigation, and it is hoped that results will be forthcoming in the near future. In particular, attempts are being made to measure the electrode potentials of martensite produced by straining single crystals of austenite and polycrystalline austenite materials.

The strain-accelerated decomposition theory seems to adequately explain the stress corrosion of mild steel in nitrate solutions.⁵⁶ The precipitations of iron nitride at the root of the notch is believed to be the causative agent, although the anodic relationship of iron nitride to the steel matrix still has not been experimentally demonstrated.

The effect of stress in promoting crack propagation during stress-corrosion by changing the potential, in a more anodic direction, of the material at the root of the crack, seems to have been disregarded generally.

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THE INFLUENCE OF STRESS ON CORROSION-PART II

As a result of their intensive investigations on the intercrystalline corrosion and stress corrosion of aluminum base alloys, several German investigators independently arrived at an electrochemical mechanism of stress-corrosion quite similar to that proposed by Dix and his associates.46 They, too, postulated that the formation of the first crack is a purely electrochemical phenomena, in which potential differences, either initially present or created during the course of the corrosion process, cause a preferential solution of the grain boundaries. However, they proposed that the crack propagation is due to an acceleration of the electrochemical process resulting from the stress concentration and strain energy at the apex of the notch lowering the potential of the grain boundary and causing an increase in the potential difference between the grain boundary and grain body. The rate of propagation of the corrosion crack was thus considered dependent on the processes which occurred in connection with the notch effects resulting from corrosion, and the differences in rates between intergranular corrosion and stress-corrosion were attributed to these effects.

In view of the recent experimental evidence, discussed in the first part of this paper, which lends possible support to this thesis, it seems worthwhile to reexamine more closely this additional role of stress.

Orientation Effects

Few investigators have considered the influence of orientation differences between grains in contributing to the development of intergranular stress-corrosion. In 1940, Dix50 reported that the grain boundaries of aluminum sheet of 99.98 percent purity, quenched in cold water from 620° C, were anodic to the grain bodies and suffered intergranular corrosion. In slowly cooled specimens the grain boundaries were cathodic and no preferential attack occurred. This behavior was attributed to the possibility of a precipitating phase at the grain boundary, not visible microscopically, which was controlled by the rate of cooling. However, these results should be reconsidered in the light of the experiments of Chaudron and Lacombe,8 described earlier in this article, who demonstrated that even in extremely high purity aluminum, intergranular corrosion would occur if the relative orientation of two adjacent crystals were not similar. Certainly, the role of orientation cannot be dismissed as a possible contributing factor in stress-corrosion of several alloy systems.

Robertson⁵⁷ recently has reported a remarkable correlation between relative orientation and susceptibility to intergranular stress-corrosion of binary copper alloys. Copper can be produced either in a random or highly oriented state depending on the conditions of working and recrystallization. In addition, certain critical concentrations of alloying elements inhibit the formation of the oriented texture in straight rolled and recrystallized binary alloys. Using the data of Tracy and Thompson⁴⁷ for the stress corrosion of binary copper alloys in ammonia, a close relationship was demonstrated between the alloy concentration which produces random orientation and

the the concentration at which the alloys become susceptible to stress corrosion. Figure 45 shows the excellent correlation for zinc, aluminum and phosphorous. For silicon, nickel, arsenic and antimony, data are not available for concentrations below those indicated by the arrows, but it is certain that the oriented texture is suppressed at lower alloy contents. Thus, it seems probable that the chemical activity of the grain boundary zone increases as the angular deviation between lattices of adjacent grains increase. It becomes necessary, therefore, to determine the importance of the chemical activity of the grain boundary, depending on orientation and effect of stress concentration at grain boundaries, in producing the acceleration of corrosion associated with stress corrosion cracking. The effect of alloving elements may be related either with the chemical or structural properties of the boundary or possibly both.

Read and his coworkers⁵⁸ postulated that the higher chemical activity of the grain boundaries of alpha brass and their more anodic potential may be due to the imperfections in the lattice resulting from the displacement of atoms from their normal lattice positions in the grain boundary regions. This would, of course, be a function of the difference in orientation between contiguous grains.

To summarize this section on the theoretical explanations of stress-corrosion, the mechanism appears to be as follows: Localized corrosion resulting from either composition differences, breakdown of protective corrosion films or orientation differences between grains, produces pits or trenches. Under the influence of stress, the stress concentration and strain energy density at the apex of the notch promotes crack propagation by either: a) rupturing corrosion films, causing electrochemical action between the filmed metal matrix and film free metal, b) accelerating the decomposition of a metastable phase, producing an anodic phase and causing electrochemical corrosion, c) lowering the potential in a more anodic direction of the material at the root of the notch or d) by mechanical propagation, i.e., by tearing of the metal underlying the notch.

Stress-Corrosion in Commercial Metal Systems

It is appropriate, at this time, to examine more

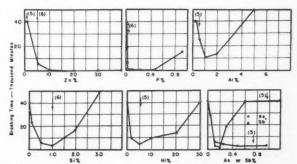


Figure 45—Breaking time of recrystallized copper alloys in ammonia atmosphere at 10,000 psi stress, compared with alloy concentration producing and random recrystallization texture shown by arrows.

(Robertson. 57)

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closely the phenomenon of stress-corrosion in several of our commercial metal systems. Only three have been selected for discussion, namely alpha brass, stainless steels and magnesium alloys, because of the interesting characteristics of the stress-corrosion reactions in these alloys and because of our lack of knowledge about the mechanisms by which the reactions proceed. Although complete agreement and understanding of stress-corrosion in aluminum alloys, nitrate cracking in mild steels and "caustic embrittlement" of boiler steels have not been achieved, nevertheless reasonable theories have been proposed which have been substantiated, at least in part, by much experimental evidence.

Stress-Corrosion of Alpha Brass

The phenomenon of stress-corrosion or "seasoncracking" in alpha brass probably has the most historical background of all of the alloys which suffer attack. The problem was brought into sharp focus by the experiences of the first World War, by the frequent cracking of brass cartridge cases, and since has been the subject of much intensive investigation. Although the numerous studies have resulted in the development of somewhat satisfactory methods for the prevention of stress-corrosion and in improved techniques for fabrication of alpha brass articles to reduce the susceptibility, nevertheless the mechanism still remains obscure. Ammonia and ammonia derivatives in the presence of oxygen, water vapor and carbon dioxide appear to be the major, if not the only, environment in which stress corrosion occurs, although Lynes has recently reported59 that alpha brass (70 Cu-30 Zn) will suffer intergranular corrosion in ferric sulfate solutions on long time exposures. Some investigators have drawn a distinction between the "season cracking" and "stress-corrosion" of brass, reserving the former for failures due to residual stresses and the latter for the effects of external loads. Since, as has been pointed out, the inherent effects of residual stresses and stresses induced by operating loads are similar, this distinction appears to be arbitrary and unnecessary.

Stress-corrosion cracks in alpha brass are predominantly intercrystalline whether in the annealed state or in the cold rolled state. As previously discussed, it has been shown that in annealed brass the grain boundaries are anodic to the grain bodies. The determination of the reason for this greater electrochemical activity of the grain boundary will no doubt provide a major impetus for arriving at the mechanism of the stress-corrosion reaction in brasses. It has been suggested that the increased grain boundary reactivity may be due to composition differences between the boundary and the grain body, precipitation of the beta phase at the boundary, concentration of lattice imperfections at the boundary, or orientation differences between grains. However, grain boundaries are not indispensable for the stress-corrosion of alpha brass. Two studies60,61 have shown that stress corrosion failure in ammoniacal atmosphere also can be produced in cast single crystals. It should be borne in mind, however, that the factors normally operative at the grain boundary may also prevail at dendrite

or "mosaic" boundaries which may be present in single crystals. The localizing effects of stress still would be operative and in one of the studies⁶¹ the cracks originated at the intersection of the slip planes with the surface of the specimen.

The effects of variation of copper-zinc ratio and of additions to commercial 70-30 brass have been intensively studied. Susceptibility to stress corrosion occurs with small percentages of zinc and increases as the zinc content increases. Wilson and his associates62 showed that no added element increases the susceptibility to cracking, but that phosphorous and silicon greatly reduce the tendency toward cracking. Silicon additions appear to be of industrial significance. The same study also revealed no difference in susceptibility between a brass of commercial purity and one made from extremely pure materials (99.999 Cu and 99.999 percent Zn) under carefully controlled laboratory conditions. Improvement in the resistance to stress-corrosion in the case of phosphorous and silicon additions apparently resulted from the presence of a second phase in the grain boundaries and a change in mode of cracking from intergranular to mixed inter- and transgranular or wholly transgranular cracking. This appears to be indicative of a change in the electrochemical characteristics of the grain boundary region. In this respect, it is interesting to note that the addition of 4 percent aluminum to [∞] brass also changes the mode of cracking from an intercrystalline to transcrystalline.

The studies on the relation between composition and stress corrosion susceptibility of the brasses recently have been supplemented by some published data by Tracy and Thompson47 on the influence of composition on the stress-corrosion cracking of high copper base alloys. It is indeed surprising that such a systematic attack on the problem, starting with high purity copper, was not made previously. Referring to Figure 45, several important features were demonstrated by their tests: a) pure copper is not susceptible to stress-corrosion cracking; b) the presence of small amounts of phosphorous, arsenic and antimony (less than 0.2 percent) under conditions of testing, were sufficient to result in stress corrosion crackings (it should be emphasized that these tests were performed under artificial laboratory conditions and should not be used for predicting service cracking of phosphorized or arsenical copper tubes); c) the cracking tendency decreases in the order—P, As, Sb, Si, Zn, Al, Ni. Brass cracks more rapidly than any of the other systems, but is low on the list because of the large amounts of zinc necessary to produce a rapid cracking rate; d) intergranular penetration in ammoniacal atmospheres, in the absence of stress, was quite marked in Cu-P alloys and was observed in Cu-Zn and several of the other alloys. This point has not been readily appreciated by previous investigators; and e) definite minima in the breaking timecomposition curves were present in most of the systems studied. The copper-zinc alloys were the only ones in which it was definitely absent.

Tracy and Thompson interpreted the data to suggest that the solute elements might concentrate at the grain boundaries and make the boundary regions

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anodic to the grain bodies by either the formation of submicroscopic precipitates, composition differences or lattice disturbances. Robertson's interpretation of the data and the close correlation between amount of alloying element required to produce random orientation effects and susceptibility to stress-corrosion was discussed earlier. Several disturbing and intriguing questions still remain, however. Granted the initiation of susceptibility might be due to orientation effects, what factors are responsible for the sharp decrease in cracking time as the amount of alloying increases, and which factors cause the well defined minima in the cracking time-composition curves for most of the alloys, with the susceptibilty decreasing after a certain concentration has been reached? In the cases of aluminum, silicon and nickel, the change in behavior occurs entirely within the solid solution range. How and why does stress influence these factors?

The study of Tracy and Thompson has provided provocative clues which should most certainly be pursued intensively. A study of the electrochemical changes which take place at the grain boundaries as a function of composition may well provide some missing pieces in the stress-corrosion puzzle of brasses and other copper base alloys. It is most certainly recognized that these studies are not simple to perform, but the techniques recently developed by Smith and his associates⁶³ for the measurement of grain boundary potential may enable such measurements to be made with at least qualitative accuracy. In addition, the effects of stress (strain), both tensile and compressive, upon these changes in potentials as a function of composition should also be investigated. Much more work needs to be done on high purity single crystals, if the true effects of strain are to be determined, in order to eliminate the effects of grain boundaries and related polarization phenomena. While it is not at all certain that such studies can be undertaken feasibly, nevertheless they appear to be requisite to the development and experimental verification of the theory of mechanism of stress-corrosion of alpha brass.

Stress-Corrosion of Stainless Steels

Austenitic stainless steels are particularly susceptible to stress-corrosion attack in acid chloride solutions⁶⁴⁻⁶⁶ and in some instances in an atmosphere of hydrogen sulfide or sulfur-containing compounds.67 The path of failure is almost always transgranular, although there have been isolated cases of intergranular cracking. This type of stress-corrosion failure is to be sharply differentiated from the intergranular corrosion phenomena to which the austenitic stainless steels are susceptible when in the "sensitized" conditions, i.e. when improper heat treatment results in the precipitation of chromium carbides at the grain boundaries. Under the influence of stress, the latter corrosion process also is accelerated by the action of stress at the roots of the corrosion notches. The difference in the two types of attack has been demonstrated clearly by the fact that specimens which were deliberately sensitized to intergranular attack cracked transgranularly under the conditions of stress-corrosion in chloride solutions. Actual experience also has shown that though the initial stages of corrosion sometimes may be intergranular, when stress-corrosion takes over, the path of failure becomes transcrystalline.68

Little is known about the mechanism of transcrystalline cracking in the austenitic stainless steels although it appears that the decomposition of austenite to martensite or ferrite may be a contributing factor. The martensite theory proposed by Waber has been discussed previously and it may be pointed out that the theory is now undergoing experimental verification. Because plastic deformation above a characteristic temperature (depending upon the composition) does not result in martensite formation but only causes slip, specimens of different compositions will be stressed above and below these "critical" temperatures and subjected to the standard boiling MgCl₂ stresscorrosion test. By such tests it is hoped to demonstrate the relationship if any, of the austenite-martensite transformation to stress corrosion cracking. In addition attempts will be made to determine the relative electrode potentials of the martensite formed and the parent austenite. From thermodynamic considerations, such martensite should be cathodic. It is quite possible that the internal stresses produced by the transformation may be a contributing factor by the production of strain energy centers which would be the local anodes.

It has been shown⁶⁹ that 18-8 stainless steels with low nitrogen and carbon are ferritic and exhibit a somewhat different corrosion behavior than the normal austenitic 18-8 types. It would be of interest to study and compare the stress corrosion behavior of a ferritic and austenitic stainless steel of virtually the same composition, differing only in nitrogen and carbon contents.

A survey of the literature of stress corrosion cracking of stainless steels reveals a most interesting observation. Few cases of the stress-corrosion cracking of ferritic or martensitic stainless steels, either as a result of laboratory tests or industrial experiences, have been reported. In those cases in which cracking did occur, it appears that a different type of mechanism may be operative. Uhlig⁷⁰ has shown that a 13 percent Cr stainless steel cracks rapidly only when hydrogen is discharged on its surface. Any condition, such as coupling with a more active metal or cathodic polarization, which drives hydrogen into the alloy sets up conditions favorable to cracking. The mechanism of such failure still remains to be worked out, but it is undoubtedly related to the extreme sensitivity of 13 percent Cr steel to hydrogen embrittlement.⁷¹ Interestingly enough cold drawn 18-8 wire did not crack under similar conditions and one can speculate that the difference in the rates of diffusion of hydrogen in ferritic and austenitic steel may be contributing factor. It is not clear whether this type of failure in ferritic stainless steels represent a case of "true stress-corrosion" or of "hydrogen embrittlement." An interesting companion experiment would have been to subject the specimen to the hydrogenizing treatment, in the absence of stress and then determine whether similar cracking would occur upon stressing.* In any event, it provides evidence that more than one possible mechanism operates to cause metals to stress crack in a corrosive environment.

Stress-Corrosion of Magnesium Alloys

Like the austenitic stainless steels, stress corrosion cracks in magnesium alloys are predominantly transgranular but show a tendency to branch. Magnesium alloys in general do not exhibit intergranular corrosion, even in the age hardened conditions. In this respect they differ markedly from the precipitation hardened aluminum alloys. It has been stated72 that there is no recorded case of failure of magnesium alloys by stresscorrosion cracking under applied service stress; all observed failures have been attributed to residual stresses resulting from fabrication or assembly operations.

It has been suggested that the transgranular path of the stress-corrosion cracks is determined by crystallographic factors and that the crack formation runs parallel to the twinning plane.73 However, evidence to the contrary exists, that the direction of the cracks is always perpendicular to the direction of stress, irrespective of the structural condition of the alloy.51,74 It would appear that additional stress-corrosion studies on single crystals of magnesium alloys, of the stress-corrosion cracks is determined by crysfying the relationship between the path of failure and crystallographic factors.

The electrochemical potentials of magnesium and the various phases and constituents which may occur in magnesium alloys have been determined,75 and the reason for the marked resistance of the Ml magnesium-manganese alloy is undoubtedly due to the lack of potential difference that exists between pure magnesium and the magnesium-manganese alloy. Additions of zinc and aluminum (AZ alloys) promote susceptibility to stress-corrosion attack. Stress-corrosion failure of magnesium castings in service, regardless of composition, is virtually unknown. It has been proposed⁷³ that the resistance of the cast structure to attack results from the fact that plastic deformation in cast alloys produces basal slip rather than twinning, whereas in oriented wrought material, twinning is the more pronounced mechanism. Similarly, the presence of zinc and aluminum in solid solution in wrought alloys would have a strengthening effect and hinder basal slip, thereby promoting increased sensitivity to stress-corrosion. This viewpoint does not seem tenable, since other investigators have not observed a preferred direction for cracking along twin bands.

One explanation for the transgranular cracking may lie in the presence of the "fine" structure which has been observed in magnesium alloys.76 This structure which is believed to be a segregation of a Fe-Al compound exists in a finely dispersed state resolvable only by electron microscopy techniques. It is believed that the Fe-Al constituent segregates along flaws or "mosaic" boundaries within the grains. As little as

* Such experiments have been reported since by Uhlig⁶¹ who found that the metal does not crack spontaneously in the absence of stress but is nevertheless embrittled and will crack if subjected to a bending stress.

.2 percent Al, in the presence of iron, is sufficient to produce a sensitivity to stress corrosion cracking in Mg-Al alloys, as illustrated in Figure 46. Additional support for this explanation is the finding that an Mg-Al alloy with .01 percent iron is more susceptible than one containing 0.0008 percent Fe.77 Although the iron rich-phase is cathodic to the solid solution a "depleted-zone" effect similar to the situation in Al-Cu alloys might provide the anodic path for corrosion. The potential differences between Fe-Al compounds and the Mg-Al solid solution are much greater than between the Mg17Al12 precipitate and the solid solution matrix. Increased precipitation of the Mg₁₇Al₁₂ compound eliminates the fine structure (which is soluble in the compound) and decreases the susceptibility to stress corrosion cracking. It is of interest to note, that in most environments, magnesium alloy sheet in the cold rolled or recrystallized condition is more susceptible to stress corrosion cracking than when the sheet has received a precipitation treatment subsequent to cold rolling.

Methods of Preventive Stress-Corrosion

Although knowledge of the exact mechanisms of stress-corrosion of commercial metals still is incomplete, nevertheless understanding of the factors involved, which has come about from numerous inten-

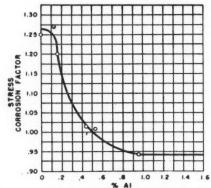


Figure 46-Effect of aluminum additions on stress corrosion cracking of magnesium alloys, (Heidenreich.76)

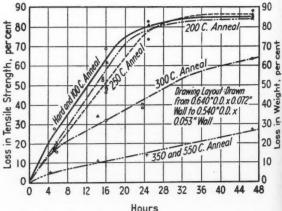


Figure 47—Effect of stress relieving heat treatment on stress corrosion of brasses. (Bulow—"Symposium on Stress Corrosion of Metals," ASTM-AIME, 1944.)

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THE INFLUENCE OF STRESS ON CORROSION-PART II

sive studies, has resulted in the development of satisfactory methods of prevention. So much so, that often it is claimed that stress-corrosion cracking under service conditions is quite uncommon. The use of barrier coatings, stress relieving heat treatments, proper design and fabrication procedures, cathodic protection and the introduction of surface compressive stresses all have been used with some degree of success.

Because stresses are an integral component of the stress-corrosion reaction, it seems only logical that the removal or reduction of residual "locked up" stresses should minimize the susceptibility to stress corrosion cracking. Such stress-relief treatments are standard practice in the manufacture of brass cartridge cases and numerous other production items. Figure 47 demonstrates the effectiveness of appropriate annealing treatments. The evidence available for brasses seems to indicate that a temperature just short of the softening or recrystallization temperature provides the optimum stress-relief treatment. If lower temperatures are used, longer stress-relief annealing times are required. It must be remembered that such

TABLE II

Effect of Stress Relief on Stress Corrosion Cracking of Mg Alloy
(AM-C 52S-H) in NaCl-K: CrO. Solution (Mears, Brown & Dix)

	Time to Failure			
Treatment	1st Specimen	2nd Specimen		
Stressed to 75 percent yield strength Heated 2 hours at 300° F, stressed to 75	8 minutes	42 minutes		
percent yield strength	20 minutes	550 hours		
Stressed to 75 percent yield strength, heated 2 hours at 300° F	Removed from 2000 hours.	test. no failures a		

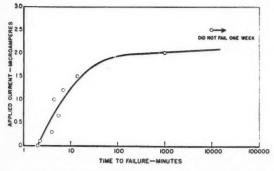


Figure 48—Effect of applied cathodic current in preventing stress corrosion cracking of AM-C57S-H Mg alloy in NaCl-K₂CrO $_1$ solution. (Mears, Brown and Dix.³⁴)

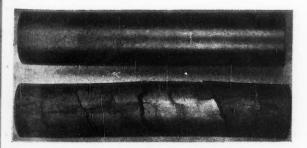


Figure 49—Comparison of two brass tubes exposed in concentrated ammonium hydroxide. Top tube cathodically protected. (Dix.⁵⁰)

thermal treatments are effective as long as they are not succeeded by operations which tend to leave the metal in a stressed condition, as illustrated by the data in Table II.⁵¹

The importance of proper design and fabrication procedures in minimizing susceptibility to stresscorrosion cannot be overemphasized. Improper assembly methods, welding techniques and heat treatments can often leave the metal product in a highly stressed and highly susceptible condition. Although residual stresses are a function of the method of fabrication, it is often possible to obtain high degrees of cold work with little or no residual stress. For example, in drawing, the die angle and ratio of hollow sinking to ironing are important factors. Shallow angle dies do not stress tubes as much as dies of steeper angles. Crampton⁷⁸ demonstrated that the intensity of residual stresses in brass tubes and the tendency to "season" crack are increased by hollow sinking instead of drawing, by greater reductions of diameter and by increased wall thickness-diameter ratios. He concluded that properly designed drawing operations would result in the production of tubes free from season cracking susceptibility. Other working operations (such as spinning, upsetting, bending) are more difficult to evaluate and stress-relieving heat treatments usually are required. Dix79 recently has provided some excellent examples of how changes in assembly methods, fabrication procedures and quenching techniques eliminated high residual tensile stresses and reduced the stress corrosion susceptibility of aluminum alloy aircraft components to a satisfactory degree.

The development of the electrochemical theory of stress-corrosion has stimulated the application of the principles of cathodic protection for the elimination of stress-corrosion attack. Most of the studies have been on a laboratory scale, but successful use under service conditions also have been reported. For example, the magnesium alloys containing aluminum and zinc (AZ31X or AZ61X) can be clad with the more anodic magnesium-manganese alloy. Sheet clad in this manner, when loaded at 90 percent of tensile yield strength in a direct tension stress, developed no cracks in a seacoast exposure of more than six months. Figure 48 shows the striking effect of applied cathodic currents in preventing the stresscorrosion failure of a magnesium (AZ61X) alloy in NaCl-K₂ CrO4 solutions.⁵¹

Similar success has been obtained in the case of brass. Tubes of 70-30 brass were fabricated by a sinking process so that they contained high residual stresses. Five days exposure of a tube to a concentrated ammonium hydroxide solution resulted in severe intergranular cracking. Making one of the tubes cathodic by an applied potential of 10 volts, resulted in no cracking in the same solution after 14 days. Figure 49 compares the two tubes after testing. In addition to the use of applied potentials for providing cathodic protection, it is possible also to employ as sacrificial anodes metals having more anodic potentials than the metals to be protected. Such anodic metals are generally used in the form of coatings. Thus, in experimental studies, zinc coatings

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have been used with some degree of success in protecting brass cartridge cases against stress corrosion in ammoniacal atmospheres.80 If cathodic coatings such as nickel, are employed on brass, the rate of stress corrosion cracking may be accelerated.51 Studies of cathodic protection of stainless steels (18-8) by dissimilar metal contacts indicated that all metals anodic to stainless steel, in NaCl-H2O2 solutions by 0.10 volts or more prevented stress corrosion failure. If the anodic potential difference was less than .10v the time for stress corrosion failure was increased over the unprotected specimen. If a metal cathodic to the stainless steel was used for the couple, the rate of stress-corrosion failure of the stainless. steel was accelerated.51 The stress corrosion of mild steel in nitrate solutions also has been effectively prevented by the use of both external currents and sacrificial magnesium anodes.53 It should be borne in mind that, for some metal systems previously mentioned, prevention of stress corrosion by cathodic protection may lead to failure by hydrogen embrittlement.

The use of surface compressive stresses has been shown to be effective in preventing stress-corrosion cracking.81 Compressive stresses at the surface may be produced by shot peening, rolling, swaging and the like. An example of the beneficial effect of shot peening on season cracking of brass is shown in Figure 50.

Attempts also have been made to prevent stresscorrosion of aluminum alloys by stabilization of the chemical composition-i.e. addition of elements which would serve to equipotentialize the grain body and depleted grain body after precipitation treatments.19 In a study of the effects of various alloying additions upon the solution potentials of the 24S Al- Cu alloy, no alloy addition studied gave the desired effect of lowering the potential of the CuAl, precipitate at the grain boundary or of the grain body; nor was the potential of the depleted grain boundary region increased significantly by any of the additions except copper.63

Advances in understanding of the phenomena of the phenomena of stress-corrosion, not only depend upon increasing our knowledge of the electrochemical relationships of the various phases that exist within alloys, but also are dependent upon advances in knowledge of the mechanisms and kinetics of metallurgical reactions in the solid state (e.g. phase transformations, precipitation, grain growth, etc.) and in understanding of the flow and fracture behavior of metals under a state of stress. Indeed, it would not be surprising if a comprehensive theory of stress corrosion would not have to wait the development of more accurate concepts concerning the fracture of metals. Studies of the nature of grain boundaries, slip planes, twin bands and other possible localized paths of corrosion, and research on the effects of strain on diffusion rates, transformation and precipitation reactions and order-disorder phenomena will provide valuable supporting information. Of direct importance are studies on the effects of strain on electrochemical potentials and rates of corrosion. It is the function of the researcher in stress-corrosion

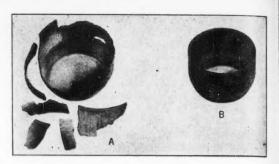


Figure 50—Effect of peening on season cracking of brass. Specimen A (non-peened) failed in 21/2 hours in ammonia atmosphere. Specimen B (lightly peened) undamaged after 100 hours in ammonia atmosphere. (Almen-"Corrosion Handbook," John Wiley & Sons.)

to correlate these advances and on the basis of known information perform critical experiments which will place understanding of the mechanisms of stresscorrosion on a sounder and more rational basis. Such research will make possible the prediction of the stress-corrosion behavior of metals under any set of conditions and the scientific development of methods of prevention or control against the insidious attack of stress-corrosion.

(Unclassified)

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Metaux et Corrosion—Figure 10. J. of the Iron & Steel Institute—Figure 11.

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Electrochemical Behavior of Zinc and Steel In Aqueous Media–Part II*

By R. B. HOXENG*

Abstract

Experience has shown that in most aqueous solutions zinc is anodic to steel and that the corrosion resistance of zinc coated steel is enhanced by the resultant electrochemical protection. Under certain conditions, howeyer, zinc reportedly became cathodic to steel. Since such an electrochemical relationship, termed a "re-versal," could be very important from the standpoint of corrosion it has been given considerable attention. Information is reported in this paper showing that constituents present in natural waters have a pronounced effect on the electrochemical behavior of zinc. All natural waters contain some calcium and magnesium which tend to form protective films on metal surfaces. Certain methods of water treatment are designed to increase the protective film formation by the addition of silicates. In laboratory tests it was found that the effect of calcium, even in small amounts, was to shift the potential of zinc in the anodic direction. Silicate additions likewise promote anodic zinc potentials, tending thereby to decrease the possibility of reversals in zinc-steel couples. Additional laboratory data are presented confirming earlier evidence that temperature is secondary to electrolyte composition in its effect on the electrochemical behavior of zinc. The anodic or cathodic behavior of galvanized steel in any water will depend on the equilibrium or balance of the various constituents of the water and can not be determined from the content of any one constituent.

Introduction

IN AN EARLIER PAPER,** detailed considera-tion was given to the fundamental electrochemical factors involved in the use of zinc as a protective coating for iron and steel. It was shown that long life of galvanized steel depends not only on the natural corrosion resistance of zinc, but also on the fact that zinc is usually anodic to steel and electrochemically protects it. Laboratory data were reported confirming previous evidence that the solution potential of zinc was variable, and that under certain conditions zinc could become cathodic to steel-such an electrochemical relationship being termed a reversal. Short time tests were reported showing that cathodic zinc potentials were not obtained unless there was oxygen present in the water. In aerated solutions bicarbonate and nitrate promoted cathodic zinc potentials, whereas chlorides and sulfates had the opposite effect. These data indicated that whether zinc would be cathodic to steel would depend on the relative balance of all

the ions in the solution. In certain solutions increasing the temperature appeared to promote reversals, but the effect of temperature was considered secondary to solution composition.

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In the present paper, additional data are presented substantiating previous results and showing the effects of other constituents normally found in waters.

Small amounts of calcium can be helpful in promoting anodic zinc potentials, and the addition of solicates can also decrease the probability of reversals in zinc-steel couples.

Experimental

The experimental procedures used in this investigation have for the most part already been described, and will not be repeated in detail. As before the specimens of zinc and steel were mounted in Bakelite and had insulated electrical leads for electrode potential measurements. Saturated calomel electrodes were again used as reference electrodes. A special Leeds and Northrup recording potentiometer was used for recording the potentials of the samples. This particular instrument is a six-point recorder having a 0 to 200 millivolt scale with a multiple range extending from —0.2 to +2.0 volts.

The experimental procedure was modified slightly to permit continuous replenishment of the solution. The stock solution was stored in overhead glass carboys, and flowed by gravity through a calibrated capillary tip into a preheat-beaker in the constant temperature bath. From the preheat-beaker the solution was syphoned into the 8-inch specimen jars, used as test beakers, and then by means of a constant level overflow syphon to drain. A flow rate of about two liters per hour was maintained throughout the runs, and samples of the overflow were analyzed at least twice daily to check on the constancy of solution composition.

Behavior of Steel

The potentials of steel electrodes exposed for 96 hours were generally in the range of 0.6-0.7 volts negative to a saturated calomel electrode (all potentials given in this paper will be on the saturated calomel electrode scale and will be negative, anodic, to that electrode). As shown in the previous paper, the

[★] A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

Case Institute of Technology, Cleveland, Ohio.

^{**} R. B. Hoxeng and C. F. Prutton, Corrosion, 5, No. 10, 330-338 (1949) Oct.

steel potentials were much more independent of both solution composition and temperature than were zinc potentials. In a few cases the potential did shift in the cathodic direction with time, however, values of 0.6-0.7 volt were attained early in the runs and it is these values which are of importance from the stand-point of reversals. It would appear, therefore, that to remain anodic to steel, the zinc potential must remain more anodic than 0.7 volt. Furthermore, if the zinc potential becomes less anodic than 0.6 volt, simultaneous exposure of zinc and steel would be expected to accelerate the corrosion of the latter.

No special curves will be shown to illustrate the potential behavior of steel electrodes. However, in the figures depicting the behavior of zinc electrodes, dotted lines will be drawn at 0.6 and 0.7 volts indicating the range of steel potentials.

Behavior of Zinc

Effect of Temperature

Short time tests reported in the previous paper indicated that temperature was secondary to electrolyte composition in its effect on zinc potential, Although not in complete accord with the findings of other investigators,2 this conclusion has been borne out by additional 96-hour tests conducted in two series of solutions. In Curve A of Figure 1 are plotted the final (96-hour) zinc potentials obtained at 50°, 60° and 70° C. in solutions containing about 100 ppm HCO₃ and 10 ppm SO₄. It is readily apparent that the zinc potentials did go through a minimum at about 60° C. When 16 ppm SiO2 was added to this solution the potentials, shown by Curve B, were shifted about 100 millivolts in the anodic direction at all temperatures, but a minimum potential was still apparent at 60° C. Upon the addition of 16 ppm SiO2 and 10 ppm calcium there was no indication of a minimum at 60° C. Actually, in this solution, the potentials observed at 70° C. were less anodic than at either of the lower temperatures. However, relatively anodic potentials were obtained at all temperatures.

Similar curves were obtained in a second series of solutions containing about 50 ppm HCO₃ and 20 ppm SO₄, Figure 2. Again minimum potentials were observed at 60° C. with and without the addition of silica (8 ppm), with this minimum disappearing when both calcium and silica were added, Curve C.

It is apparent therefore that, depending on the composition of the solution, it might be concluded either that temperature was a controlling factor or that temperature had absolutely no effect on the potential of zinc. Considering all available data, our conclusion would be that the effect of temperature is secondary to that of electrolyte composition.

In certain solutions, however, a definite temperature effect was observed and is worthy of additional consideration. Before offering an explanation for the observed behavior it should be pointed out that for those solutions which gave a minimum zinc potential, the temperature at which that minimum occurred coincided roughly with the temperature which has been reported as giving maximum zinc corrosion rates in solutions left open to the atmosphere, that is, about 60° C.3.4 An explanation can be advanced to explain

the effect of temperature on the potential of zinc, which will also suffice to explain, at least qualitatively, the reported corrosion behavior. (Indeed, any adequate explanation must satisfactorily relate the potential and weight loss behavior:) As is well known, the mobility of disolved oxygen increases with temperature. Since oxygen depolarizes the cathodic reaction, the effect of increasing the temperature would be, therefore, to shift the over-all potential of the zinc electrode in the cathodic direction and to increase the local action current on the surface of the metal, that is, increase the corrosion. However, at higher temperatures, another factor becomes important and eventually controlling, namely the decreased solubility of oxygen. As a result, upon increasing the temperature, less oxygen is available for the cathodic reaction, so the potential of the zinc electrode returns in the anodic direction and the corrosion rate decreases.*

Such an explanation is adequate for those solutions in which minimum potentials were observed. For other solutions all that need be said is that depolarization of the cathode by oxygen is probably not a controlling factor in determining the zinc potential, hence it would not be expected that the potential would show the same temperature dependency. In other words, temperature dependency of potential will be observed only in so far as the particular electrochemical reaction dominating the over-all electrode potential is temperature dependent. There is temptation to look for an analogy in the corrosion behavior of zinc as evidenced by weight loss. For the specific test conditions employed the reported data showing maximum zinc corrosion rates at about 60° C. are unquestionably valid. However, how applicable are the conclusions drawn from these tests to other test conditions?

So far in this investigation, only one method of studying the effect of temperature has been employed, namely continuous exposure at a given constant temperature, with only one temperature per test. It was considered advisable to obtain such information before making tests employing cyclic temperatures. The latter condition is of course of great practical importance and will be studied in future tests.

Effect of Silicates

Silicates occur naturally in many waters and are often intentionally added to decrease the corrosivity of waters. It is beyond the scope of this article to discuss the complexities of silicate chemistry other than to say that both ions and electrically charged colloidal agglomerates undoubtedly are formed upon the hydrolytic dissociation of sodium silicates. For the moment observations will be reported only as to what happened to the zinc potential when silicates were added to aqueous solutions, without attempting any complete explanation.

Under the conditions of testing employed in this investigation, the effect of silicate additions was defi-

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^{*}It is felt that at least one other factor should be considered in the above mechanism, namely, the bicorbonate ion. In the previous paper evidence was presented showing that the action of the bicarbonate ion probably was to depolarize the local cathodic areas of corroding zinc surfaces, thereby suplementing the action of oxygen.

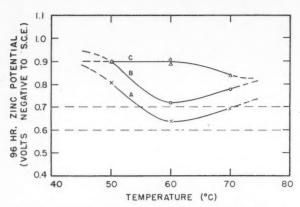


Figure 1—Effect of temperature on zinc potential in various solutions. Solution composition (nominal): 100 ppm HCO2, 10 ppm SO4, pH 7.9 with additions as follows: Curve A, none; Curve B, 16 ppm SiO2; Curve C, 16 ppm SiO2 and 10 ppm Ca.

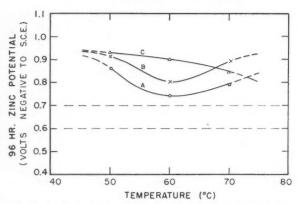


Figure 2-Effect of temperature on zinc potential in various solutions. Solution composition (nominal): 50 ppm HCO2, 20 ppm SO1, pH 7.9 with additions as follows: Curve A, none; Curve B, 8 ppm SiO2; Curve C, 8 ppm SiO2 and 10 ppm Ca.

nitely to shift the potential of zinc in the anodic direction (provided, of course, that the zinc potential was not already more anodic than 0.9 volt prior to the silicate addition). This is illustrated by data presented above on the discusion of the effect of temperature. Comparison of Curves A and B of Figures 1 and 2 clearly show that silicate additions shifted the 96-hour zinc potentials in the anodic direction. In Figure 3 are plotted additional 96-hour potential data obtained in three series of solutions at 60° C. Solutions containing 50 ppm HCO3, 10 ppm SO4 and various amounts of silicate were employed in obtaining the potentials represented by Curve A. When the alkalinity was increased to 100 ppm the series of potentials represented by Curve B were obtained. It should be noted that in addition to illustrating the effect of silicate additions, a comparison of Curves A and B substantiates the conclusions made in the previous report to the effect that increasing the bicarbonate concentration shifted the potential of zinc in the cathodic direction.

Curve C of Figure 3 shows the effect of silicate additions on the zinc potential in a solution containing 10 ppm calcium in addition to the bicarbonate and sulfate considered in Curve B. Here again the effect of silicate addition was to shift the zinc poten-

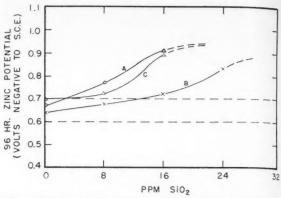


Figure 3—Effect of silicate concentration on zinc potential at 60 degrees C. Solution composition (nominal): 50 ppm HCO₃, 10 ppm SO₄, pH 7.9 with additions as follows: Curve A, none; Curve B, 50 ppm HCO₃; Curve C, 50 ppm HCO₃ and 10 ppm Ca.

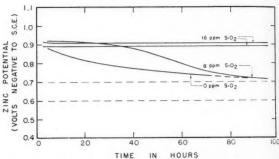


Figure 4—Effect of silicate concentration on zinc potential at 60 degrees C. Solution composition (nominal): 100 ppm HCO₃, 10 ppm SO, pH 7.9.

tial in the anodic direction. (The effect of calcium is discussed below.) From this curve it would be concluded that the intermediate amount of silicate, 8 ppm, had practically no effect. It is helpful to consider the actual time potential curves from which Curve C was obtained. These are given in Figure 4. It is readily apparent that the addition of 8 ppm of silica had a real effect for the first 40 hours of exposure, but by the end of 96 hours the effect on the zinc potential was negligible.

The conclusion which may be drawn from these data is that the addition of silicates to waters did tend to make the zinc potential more anodic, thereby decreasing the danger of reversal in the zinc-steel couple. It is not possible without additional information, to explain completely the mechanisms of how silicates shift the zinc potential in the anodic direction. Film formation on the local zinc cathode areas resulting in cathodic polarization would explain the observed behavior. However, it could as well be explained on the basis of increased anodic area. Further work is planned on this very important aspect of silicate inhibition, but for the present it is sufficient to say that silicate additions decreased the probability of reversals in zinc-steel couples.

Effect of Calcium

From the standpoint of influence on aqueous corrosion, probably no constituent has been studied as extensively as has calcium. No attempt will be made here t if any point ior of was a calciu 3. Al effect Curve for C calciu of zir The

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ZINC POTENTIAL

ELECTROCHEMICAL BEHAVIOR OF ZINC AND STEEL

here to review the literature on this subject. Little if any work has been done, however, from the standpoint of the effect of calcium on the potential behavior of zinc. An indication of how the zinc potential was affected by the presence of, or the addition of calcium to the water in these tests is given in Figure 3. Although these data pertain particularly to the effect of silicate additions, the solutions used for Curves B and C differed only in the fact that those for Curve C contained 10 ppm calcium. The effect of calcium was clearly therefore to shift the potential of zinc in the anodic direction.

The effect of calcium additions can be illustrated further by showing the time-potential curves obtained in solutions varying only in their calcium con-

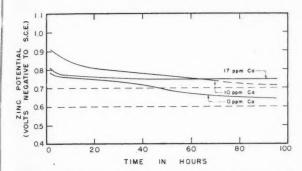


Figure 5—Effect of calcium concentration on zinc potential at 60 degrees C. Solution composition (nominal): 100 ppm HCO₃, 10 ppm SO₄, pH 7.9.

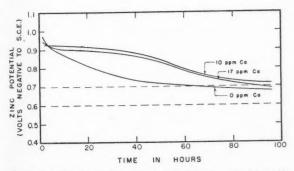


Figure 6—Effect of calcium concentration on zinc potential at 60 degrees C. Solution composition (nominal): 100 ppm HCO₃, 10 ppm SO₄, 8 ppm SiO₂, pH 8.0.

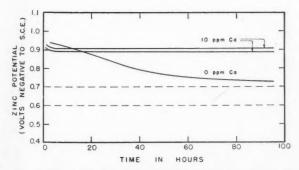


Figure 7—Effect of calcium concentration on zinc potential at 60 degrees C. Solution composition (nominal): 100 ppm HCO₂, 10 ppm SO₄, 16 ppm SiO₂, pH 8.0.

tents. Figures, 5, 6, and 7 show the effects of calcium additions on the time-potential behavior of zinc electrodes in a series of solutions containing about 100 ppm HCO₃, 10 ppm SO₄ and O, 8 and 16 ppm SiO₂, respectively. The curves of Figure 5 indicate that in these solutions containing no silica, the effect of calcium additions was to give slightly more anodic zinc potentials. Increasing the calcium concentration from 10 to 17 ppm had little effect other than an apparent tendency to give values which were steadier with time. In solutions containing 8 ppm SiO2, Figure 6, the addition of calcium appeared to cause more anodic potentials during 40-50 hours of test, however by the end of 96 hours, the difference was negligible. When the silicate concentration was increased to 16 ppm, Figure 7, the addition of 10 ppm calcium was sufficient to give steady anodic zinc potentials. The agreement on check runs containing 10 ppm calcium was excellent as indicated.

These data indicate that the addition of even small amounts of calcium generally had the effect of causing more anodic zinc potentials. How much the potential is shifted or whether it will remain steady at anodic values is dependent on the composition of the solution as a whole. Qualitatively, this electrochemical effect can be explained on the basis of polarization of local zinc cathodes. The formation of calcium carbonate films on the cathodic areas could account for such polarization. Furthermore, because of the localized regions of higher pH, the solubility product of calcium carbonate could be exceeded at the cathodic areas even though the solution as a whole may not approach saturation.

In the presence of certain concentrations of silica, small amounts of calcium were particularly effective. Undoubtedly the alkalinity and pH of the solution are important factors to be considered in evaluating the over-all effect of calcium. The significant fact shown above is that in certain solutions, small amounts of calcium can act to retard or prevent reversals in zinc-steel couples. This is, of course, very desirable and supplements the long recognized value of calcium as a corrosion inhibitor.

Effect of pH

Several runs were made, exploring the effect of pH on the potential of zinc electrodes. It is, of course, impossible to vary the pH in a series of solutions and have everything else remain constant. An effort was made to maintain a fixed bicarbonate ion concentration in each series of tests realizing that the carbonic acid and carbonate ion concentrations would vary with pH. With the bicarbonate ion concentration held constant the carbonic acid concentration is directly proportional, whereas the carbonate ion concentration is inversely proportional to the hydrogen ion concentration. In the tests reported below, constant sulfate ion concentration and varied pH were obtained by proper additions of sulfuric acid, sodium sulfate and sodium hydroxide. Sodium bicarbonate was added as before to adjust the bicarbonate ion

Curve A of Figure 8 is based on 96-hour potentials of zinc in solutions containing 20 ppm SO₄, approxi-

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mately 35 ppm HCO₃ with pH as indicated at 60° C. A minimum potential is indicated in the pH range between 7 and 8. However, the over-all variation is not large. Parallel behavior was observed in a series of solutions containing 100 ppm HCO₃, 10 ppm SO₄ and 10 ppm Ca as shown by Curve B. In a series of solutions containing both silica and calcium, Curve C, relatively anodic potentials were observed at all values of pH. Actually the values at pH 7.9 were slightly more anodic than those at either a higher or lower pH. In a similar solution without calcium, the values at the intermediate pH were again the least anodic, as shown in Curve D.

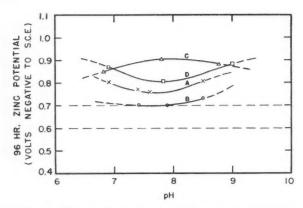


Figure 8—Effect of pH on zinc potential in various solutions at 60 degrees C. Solution compositions (nominal): Curve A, 35 ppm HCO₂, 20 ppm SO₄; Curve B, 100 ppm HCO₃, 10 ppm SO₄ 10 ppm Ca; Curve C, 50 ppm HCO₂, 20 ppm SO₄, 8 ppm SiO₂; Curve D, 50 ppm HCO₃, 20 ppm SO₄, 8 ppm SiO₂:

In view of the fact that so many solution factors vary simultaneously with pH, the results reported above must necessarily be considered as preliminary in nature and of significance only for those specific test conditions. Although it is apparent that in solutions of these compositions the variation of zinc potential with pH was not excesively large, generalizations should certainly not be made. It should be particularly pointed out that if the pH of a specific water is varied over the pH range of 7 to 9, the bicarbonate ion concentration will not remain constant but will go through a maximum. This maximum will occur at a pH of about 8.5 at 25° C., and will occur at progressively lower values of pH as the temperature is increased, being about 7.9 at 100° C.

Conclusions

For many years it was assumed that zinc was always anodic to steel and cathodically protected it in all aqueous solutions. The fact that galvanized steel pipe has been so widely used and has given satisfactory results, indicates that zinc is generally anodic to

steel. Instances were noted in hot water service. however, where the appearance of the corroded pipe indicated that the zinc might have been cathodic

From the research reported in this and a previous paper much has been learned of the electrochemical behavior of zinc and steel. Although the behavior of steel was about the same in most solutions tested. the potential of zinc was very dependent on the composition of the solution. In the absence of oxygen the zinc was always anodic. In aerated solutions, bicarbonates and nitrates were found to promote cathodic zinc potentials, whereas chlorides, sulfates, silicates and calcium all acted in such a way as to give more anodic zinc potentials. The final behavior of zinc in any water cannot be determined from the content of any one constituent but will depend on the equilibrium or balance of the various constituents.

On the basis of laboratory tests it has been shown that temperature is secondary to electrolyte composition in its effects on the electrochemical behavior of zinc. In some solutions the zinc was cathodic at about 60° C., however, in other solutions there was no indication of such a temperature effect.

Although the work reported thus far has been with relatively pure zinc, it is planned to extend the investigation to the behavior of galvanized steel under actual service conditions.

Acknowledgments

The author expresses his indebtedness to the Committee on Steel Pipe Research of the American Iron and Steel Institute which is sponsoring this research project at Case Institute of Technology.

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DISCUSSION

By Walter Beck, Lehigh University, Bethlehem, Pa.:

The fact that the addition of silicate promotes anodic Zn potentials and increases the formation of protective films is of considerable practical significance. In this respect it would be of interest to follow the corrosion behavior of the iron, coupled galvanically with Zn by weight loss measurements while varying time of exposure, the current density and concentration of silicate.

It can be expected that measurements of the weight loss and the electrode potential also will give more information with respect to the electrochemical mechanism which controls the process of corrosion protection brought about by silicate action.

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An Electrochemical Mechanism Of Corrosion Inhibition by Chromates, Nitrites and Other Oxidants *

By MARCEL POURBAIX* and PIERRE VAN RYSSELBERGHE**

Abstract

This article is based upon a communication at the discussion on inhibitors at the Gordon Research Conference on Corrosion at New London, New Hampshire, July, 1949, and constitutes a portion of a theoretical and experimental study of inhibitors based upon the and experimental study of ministers based upon the use of the polarographic method. It classifies corrosion inhibitors as: 1) surface conversion inhibitors; 2) adsorption inhibitors; 3) diffusion inhibitors, with examples of each. A brief analysis of the mechanism of each type is given. The role of the inhibitor is defined in a discussion of corrosion of iron by a solution tree of oxygen with inhibitor absent. This phenomefree of oxygen with inhibitor absent. This phenomenon is studied using polarization curves. A further discussion considers the corrosion reaction when a chromate or nitrite has been added. Minimum inhibitor concentration for protection is shown to be that which for a given oxygen concentration, brings the potential of the metal to a value corresponding to its passivation value. The electrochemical mechanism described shows that, at inhibitor concentrations insufficient for protection, both the inhibitor and oxyare consumed in reduction reactions. authors are attempting to make direct polarographic determinations of inhibitor consumption.

CONVENIENT classification of corrosion inhibitors is that given, for instance, by Misch and McDonald: 1) surface conversion inhibitors; 2) adsorption inhibitors; 3) diffusion inhibitors. A few examples will suffice to characterize the three classes: to Class 1 belong antimony and arsenic salts, chromates, nitrites, phosphates; to Class 2 belong thiourea and a number of amines; to Class 3 belong gelatin, casein and various colloids. In the present article only certain inhibitors of Class 1 will be considered. First it is suggested that this class be divided into two sub-classes: the oxidants and the nonoxidants. The oxidants include chromates, nitrites and also oxygen itself. As will be seen, their inhibiting power is the result of their participation in a primary reaction in which they are reduced. The non-oxidants inhibit corrosion through secondary reactions of these inhibitors with products of primary corrosion processes. For instance, a soluble fluoride inhibits the corrosion of magnesium because it causes precipitation of insoluble magnesium fluoride with the magnesium ion formed in the primary corrosion process. If additional classification of inhibitors into cathodic and anodic types is desired, the soluble fluoride could be regarded as an anodic inhibitor because it reacts with the product of an anodic reaction. A soluble nickel salt will cause precipitation of nickel hydroxide with the hydroxyl ion formed in a primary cathodic reaction and could thus be regarded as a cathodic inhibitor. Calcium bicarbonate is also a cathodic inhibitor of this sub-class because it leads to precipitation of calcium carbonate in the basic solution resulting from the cathodic formation of hydroxyl ion by oxygen reduction.

A possible electrochemical mechanism of the inhibition by oxidants will be examined now. The main effect of such an inhibitor on the properties of the system corroding metal + corrosive solution is the introduction of a new cathodic reaction with its corresponding potential. There is therefore an additional polarization curve to be considered in the establishment of the steady state conditions of the corrosion process.

In order to show with sufficient clarity the role of the inhibitor we first consider the corrosion of iron in a solution entirely free of oxygen and in the absence of any inhibitor. Polarization curves will be used plotted according to the method of Evans² which is familiar to all students of corrosion. In general, however, the authors prefer the type of plot appearing extensively in the writings of Pourbaix4, 5 and characterized by the use of a positive current axis for anodic currents and of a negative current axis for cathodic currents. This latter type of plot facilitates the establishment of close connections with other types of polarization diagrams, such as polarograms, for instance.

In Figure 1 E_a represents the reversible potential of iron in equilibrium with some small ferrous ion concentration and E_e represents the reversible potential of hydrogen in equilibrium with hydrogen ion at the pH of the solution. Curve a is the polarization

^{*} Based upon a communication at the discussion on inhibitors at the Gordon Research Conference on Corrosion at New London, N. H., July, 1949. Submitted for publication November 7, 1949.

""Chef de Travaux" at the Laboratory of Applied Physical Chemistry, Engineering School, University of Brussels, Belgium.

^{**}Professor of Chemistry at the University of Oregon, Eugene, Oregon. The present article constitutes a portion of a theoretical and experimental study of inhibitors based upon the use of the polarographic method. This research project, entitled "Polarographic Study of Corrosion Phenomena" is being carried out under a contract between the Office of Naval Research and the University of Oregon.

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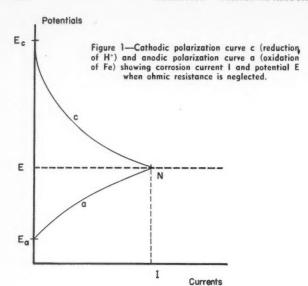
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curve for the anodic process Fe := Fe++ + 2 e-, which is probably subject to little overvoltage if any, and curve c is the polarization curve for the process 2 H⁺ $+2e^{-}=H_2$, which on the contrary is in general subject to a considerable overvoltage (i.e. a considerable lowering of the potential must occur before the process can start). This is indicated by the retarded increase of the cathodic current. If one neglects the ohmic drop of potential the intersection point of curves a and c determines the corrosion current and the corresponding potential since there must be equality in the numbers of electrons involved in the anodic and cathodic processes. When the cathodic process is exclusively the reduction of hydrogen ion the resultant potential E will never be high enough to bring iron to its passivation potential and, therefore, there can never be any suppression of corrosion. Passivation potentials of iron can be read directly on Pourbaix's thermodynamic potential-pH diagrams for iron.4

When the solution contains oxygen, for instance if it is air saturated, the reduction potential of oxygen E_{c_1} and that of hydrogen ion E_{c_2} have to be considered. Electrons can now be consumed by the two simultaneous processes

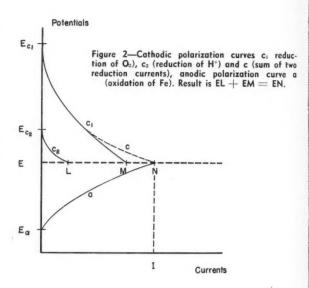
$$O_2 + 2 H_2O + 4 e^- = 4 OH^-$$

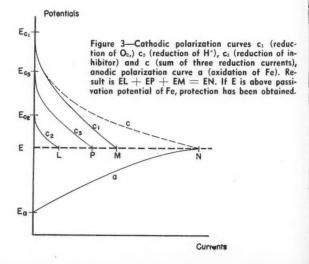
 $2 H^+ + 2 e^- = H_2$

of which the second may be absent. Electrons are produced by the anodic oxidation or iron. The process of oxygen reduction is in general subject to a considerable overvoltage. The steady state of corrosion corresponds to the point N of curve a of Figure 2 such that MN = EL. Point N is the intersection with curve a of a curve c obtained by addition of the abscissas of curve c₁ and c₂. The total cathodic current is then EL + EM and is equal to the anodic current EN. It may be possible that, at sufficiently high oxygen concentrations, the current EM may tend to be large enough to bring the potential E to the passivation value, in which case the corrosion process stops, the anodic polarization curve coming

then to an abrupt end. If the reduction of oxygen can bring about such a situation it may be said that oxygen is then a true inhibitor of the first sub-class defined above.

Let it then be supposed that a certain amount of chromate or nitrite has been added to the solution. A new reduction reaction and its potential have now to be considered and there arises the situation of Figure 3 in which, in addition to the cathodic polarization curves for oxygen and hydrogen ion reduction, there is the polarization curve for the reduction of the inhibitor. The contribution EP to the total cathodic current will increase with the amount of inhibitor and there is thus the possibility, in case the oxygen reduction current EM is limited by the oxygen concentration remaining equal, for instance, to its value at air saturation, that the total current EN (with MN = EL + EP) might correspond to a potential at least equal to the passivation potential of iron for the solution under consideration. In Figure 4 the polarization curves are plotted according





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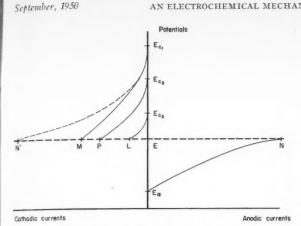


Figure 4—Same case as that of Figure 3 with cathodic and anodic currents separated. Result is EN' = EL + EP + EM = EN.

to the method of Pourbaix4 for comparison with the Evans type of diagram. The minimum inhibitor concentration is thus that which, for given oxygen concentration, brings to the passivation value the potential corresponding to the corrosion current. In the case of iron the passivation state is due to the formation of ferric compounds which are more insoluble than the corresponding ferrous compounds. Such a situation may perhaps be regarded as a condition for the existence of passivation. For instance, copper has a cupric hydroxide more soluble than its cuprous hydroxide and there is no passivation. Manganese and chromium are cases which are possibly similar to that of iron.

When passivation potentials have been reached through a sufficient contribution to the cathodic current by addition of inhibitor the metal will then acquire a potential high enough to preclude the possibility of any reduction reaction, i.e., it will reach a potential at least as positive as that at which oxygen reduction could otherwise begin. In a solution in which the ferrous ion concentration is 10-6 mole per liter (the arbitrary limit between corrosion and its absence previously chosen by one of the authors⁵) the iron potential is -0.62 volt. If the pH is 7 the

reversible reduction potentials are about as follows: -0.42 volt for hydrogen ion, +0.8 volt for oxygen, +0.4 volt for chromate ion (reduction to chromic hydroxide), and +0.2 volt for nitrite ion (reduction to ammonia), while the passivation potential of iron is about -0.2 volt. The curve corresponding to the sum of the cathodic currents must thus intersect the anodic current curve at a value of the potential at least as high as -0.2 volt if passivation is to be obtained.

The electrochemical mechanism described above shows that, at inhibitor concentrations insufficient for protection, both the inhibitor and oxygen are consumed in reduction reactions. When protection is obtained through sufficient inhibitor concentration neither the oxygen nor the inhibitor is being consumed. These implications of the mechanism are being verified by polarographic determinations of oxygen consumption by the method previously described by one of the authors6 for the case of inhibition of the corrosion of iron by nitrite and chromate. An attempt also is being made to make direct polarographic determinations of inhibitor consumption. This work will be reported in detail in other papers.

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Discussions

Discussion on "CORROSION ON NEW DISTIL-LATION UNIT PROCESSING LOW SULFUR CRUDES," by D. L. Burns, Corrosion 6, No. 6, 169-177 (1950) June.

By E. F. Tibbetts, The Lummus Company, 385 Madison Ave., New York, N. Y.:

First, I'would like to congratulate Mr. Burns for such an excellent report of service experience. He has brought out a number of points which are frequently overlooked in design of atmospheric and vacuum units.

I would like to ask if it was found necessary to employ pH recorders or automatic pH controllers on the water condensate drawoff to control ammonia injection in overhead lines to avoid corrosion of condensers or whether manual control was satisfactory. There has been quite a bit of difference of opinion on this point among corrosion engineers, some claiming that excessive pH variations occur unless recorders or controllers are used.

Author's Reply:

It has not been considered necessary to employ pH recorders or controller on the water condensate draw-off. In general, neutralization of overhead streams by use of ammonia should not require fine control if the nature of the crude charged does not vary too much. Manual control has the advantage of simplicity and requires little or no maintenance.

Questions by Leon D. Cook, Jr., Wyandotte Chemicals Corp., Pilot Plant, Wyandotte, Mich.:

1. Was impingement attack observed on the steel baffles and shell of the overhead condenser for the atmospheric tower prior to neutralization?

2. If so, did neutralization by ammonia injection appreciably reduce this type of attack?

Author's Reply:

No impingement attack occurred on the steel wearing plate near vapor inlets of overhead condensers.

The corrosion of steel baffles and shells was of a general nature accompanied by severe pitting, principally in the lower half of the condensers.

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Discussion on "CORROSION OF METALS BY INSECTICIDAL SOLUTIONS," by George S. Cook and Nancye Dickinson. Corrosion 6, No. 5, 137-139 (1950) May.

By H. O. Teeple, The International Nickel Company, 67 Wall St., New York 5, N. Y.:

Do I understand correctly that in reporting pitting which occurred on the various specimens you extrapolated the depth of pit for an eight weeks exposure to an inch penetration per year value? If so, and if you do not have the pit depth measurements for the eight week exposure period, would you please include these data in the written discussion of your interesting paper.

Authors' Reply:

The pit depths were measured in millimeters at the conclusion of the eight week exposure. The results could have been reported as millimeters penetration for eight weeks but were converted to ipy since this is a more standard method of reporting results.

It is admitted there is no basis for assumption that the extent of corrosion in eight weeks would reproduce itself in a degree for every additional eight weeks of exposure and thereby make it possible to predict in eight weeks what the pit depths of a one year exposure would do. For a complete investigation of corrosion rate versus time, separate samples would have to be removed from the test solution periodically during the test for cleaning and measurement. This amount of work was considered impractical in this preliminary investigation. However, in any future work on this problem in which the number of metals and test solutions are reduced in number, the factor of extent of corrosion as a function of duration of exposure will be definitely examined.

The data requested is shown in the following table.

Pitting Millimeters Penetration in Eight Weeks

	A	В	C	D	1	L	0
METAL	Distilled Water	5% DDT Distilled Water	5% NaCl	5% DDT in 5% NaCl Solution	DDT Emulsion	Chlordane	Sodium Arsenite
Stainless Steel Aluminum Copper Aluminum Alloy Steel Magnesium Alloy	None None None None 0.10 None	None None None 0.20 0.30 1.95	None None .05 0.10 None 3.11	None None 0.20 0.10 0.30 1.30	None None None 0.10 0 10 None	None None None 0.30 0.40 0.90	None 0.10 0.10 0.15 None None

Question by R. W. Flournoy, Corn Products Refining Company, Argo, Ill.:

Were the corrosion tests in the insecticide solutions made by complete immersion of test pieces in the liquid phase or were vapor phase tests included?

Authors' Reply:

The test samples were immersed to a depth of four inches of their six inch length. The two inch length of sample which was exposed to the vapor only in general was not affected. Occasionally the insecticide solution metal-vapor interface was more severely corroded than the totally immersed portion. The Mdd values reported were calculated on the total loss in weight distributed over only the four inch length that was totally immersed. Admittedly the reported value may be somewhat higher than would have been the case if the entire sample had been immersed. However, in actual use the tanks would be partially filled, with the upper tank surface exposed only to vapor which would exert its indeterminate influence on the corrosion rate of the metal immersed in the solution. The laboratory test was set up to duplicate this factor.

Question by Robert S. Dalrymple, Kaiser Aluminum & Chemical Corp., Box 1451, Spokane 6, Wash.:

Was 2-4d acid or sodium salt used in this test?

Authors' Reply:

The 2-4d acid was used.

Question by Richard S. Egly, Commercial Solvents Corporation, Terre Haute, Ind.:

In tests which we have made on emulsifiable solutions of technical benzene hexachloride, lindane, and dilan, we found that the nature of the emulsifier and solvent greatly affected corrosion rates. Were any effects of emulsifier or solvent noted in your work with D. D. T.?

Authors' Reply:

The effects of different emulsifiers or solvents on the corrosion rate of metals was not studied in this investigation. This factor will be given consideration, however, if further work is done on the subject.

Discussion by Charles G. Gribble, Jr., Metal Goods Corporation, 711 Milby, Houston, Texas:

The question was asked as to the grade of stainless used and the answer was given as 18-8.

The aluminum alloy used was 24ST. This is not generally considered as an alloy resistant to salt water corrosion. It is therefore suggested that a test of this material in salt water without D. D. T. would further prove the effectiveness of D. D. T. as an inhibitor.

It is suggested that in further tests of aluminum alloys, the alloys not containing copper be considered. These alloys, such as 61ST, are generally considered as more corrosion resistant than the copper bearing alloys.

Authors' Reply:

The results as shown in Table II demonstrate that the D. D. T. in salt solution did inhibit corrosion of the aluminum, 24ST aluminum alloy, steel and FS-1a magnesium. In any further investigation of this problem emphasis will be placed on the more corrosion resistant aluminum alloys.

Discussion on "SURFACE PREPARATION VAL-UES AND SANDBLASTING ECONOMICS," by A. J. Liebman, Corrosion 6, No. 5, 151-157 (1950) May.

By George Diehlman, Research Laboratories, National Lead Company, 105 York St., Brooklyn, N.Y.

Flame conditioning provides a worthwhile method of surface preparation. Mention was made of its dehydrating action and also that a follow-up with wire brushing was desirable. Occasionally the practicability of capitalizing on the warm dry surface with the first paint coat is questioned on erected structures in the field such as bridges. Can you give us the benefit of your experience in this connection?

Authors' Reply:

We have conducted some experiments along those lines and have found that the value of a warm dry surface over a cold dry surface is very minute as long as the temperature is held within the practical performance limit of the paint. This is somewhat above the freezing point of an oxidizing coating, and in some cases may be lower than that for a coating which dries by evaporation. In the writer's opinion, it is more important to remove partially loose and upturned scale with a wire brush than to be able to apply a paint while the steel is still warm.

Question by Walter B. Meyer, Nooter Corporation, 1400 S. Second St., St. Louis 4, Mo.:

What is your impression of the merits of silica sand as opposed to steel grit from the standpoint of incorporating particles of steel dust at various levels throughout the protective coating, thus causing "islands of corrosion"?

Authors' Reply:

Both the silica sand and the steel grit have a definite place and value in various surface preparation work. In operations where humidity can be so controlled that steel grit can be used, it has been found more economical to employ it over the use of silica sand. The "islands of corrosion" suggested by the questioner are caused mainly by improper selection of steel grit or the improper use of the blasting equipment.

Discussion on "CATHODIC PROTECTION OF FOURTEEN OFFSHORE DRILLING PLATFORMS," by E. P. Doremus and G. L. Doremus. CORROSION 6, No. 7, 216-224 (1950) July.

By F. L. LaQue, The International Nickel Company, 67 Wall St., New York, N. Y.:

The authors mentioned the use of calomel half cells as reference electrodes for measuring the potentials of submerged steel surfaces of offshore drilling platforms and commented on the fragility of these devices and the consequent care required in their use.

The suggestion is made that high purity (99.99%)

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ne 10 10 15 ne ne zinc will serve as a satisfactory and relatively rugged reference electrode for checking whether a protective potential has been achieved and is being maintained. Experiments with high purity zinc in sea water at Kure Beach, N. C. have indicated that it is not very sensitive to variations in sea water temperature and velocity and is not too readily polarized and should, therefore, serve as a reasonably satisfactory reference electrode for use offshore in the Gulf or elsewhere where sea water not peculiarly contaminated will be present.

It can be assumed that such high purity zinc will exhibit a potential relative to a saturated calomel half cell of about -1.035 volt plus or minus 10 millivolts. On the basis that a potential relative to a saturated calomel half cell of about 0.80 volt is evidence of satisfactory protection, it can be assumed that with pure zinc as a reference electrode any measured potential not greatly in excess of about + 0.20 volt represents satisfactory protection.

Since potentials relative to a saturated calomel half cell in excess of —1.11 volt—beyond the range of many portable potentiometers—are sometimes encountered, the use of pure zinc as a reference electrode has the added advantage that the values observed are always well within the range of the available instruments.

It is believed that the values secured with zinc are precise enough for all practical purposes, but if greater accuracy is desired, it is a simple matter to calibrate a zinc electrode vs a calomel half cell before, after or during any series of observations.

Some thought might also be given the possibility of using permanently installed zinc electrodes as references for periodic checks of the potentials of individual piles or portions of piles.

For potential surveys close to protected surfaces, it is a simple matter to mount a zinc wire or rod in an insulating support that will hold the zinc at the desired distance from the surfaces to be explored. Zinc is being used with apparent satisfaction for these purposes at the new Inco Marine Test Station at Kure Beach (Harbor Island) North Carolina.

Question by T. R. B. Watson, Dominion Magnesium Ltd., 67 Yonge St., Toronto, Canada:

Did you notice any significant difference in the output of anodes placed right on the bottom, and if not why did you suspend them?

Authors' Reply:

Location of magnesium anodes near the mud line had no noticeable effect on current output. The anodes were suspended at this point to provide maximum stability in rough seas.

It was felt that suspending the anodes in this manner would be superior to laying them on the bottom, for the latter would give rise to the dangeer of "shorting" to horizontal platform bracing at the mud line as well as cable failure due to excessive flexing under slack conditions.

Discussion on "CORROSION IN CONDENSATE AND IN HIGH PRESSURE SWEET OIL WELLS," by R. C. Buchan. Corrosion 6, No. 6, 178-185 (1950) June.

By T. S. Zajac, Shell Oil Company Incorporated, Shell Building, Houston, Texas:

The author is to be commended on his general but comprehensive coverage of a rather complex and broad subject. His comments pertaining to the mechanical aspects of the tubing coupling problem in high pressure corrosive operations are indeed timely. That leakage in tubing couplings is a real problem is now being recognized and many of the operators who are experimentally using expensive alloy tubes are having these tubes equipped with special connections of the pin and box type to circumvent leakage problems.

It is recognized that some of the author's generalized statements were necessary when dealing with a subject of this scope. However, in the interest of avoiding any misunderstandings about the applications of the various corrosion alleviation measures discussed, it may be well to elaborate a little on this matter of what is best to use. It should be clearly understood that the problem in question is indeed a complex one. It is concerned with old and new wells, wells with short lives and with relatively long lives. wells producing greatly differing fluids, and those which are accessible and relatively inaccessible. The solution to the problem under these diverse conditions must then be one which is practical, effective. and last but not least, economical. It would appear on the basis of present knowledge that the old wells, and possibly even new ones, with relatively short lives, (say up to 10 years) might be treated more economically with some type of inhibitor. However, when considering wells with operating lives of 10 to 20 years and more, the use of corrosion resistant tubing appears quite attractive. Likewise, when considering wells with ultra high pressures, those that are relatively inaccessible and when considering a small number of wells, the use of alloy tubing again appears attractive. It is reasonable to believe, as pointed out by Mr. Buchan that the use of alloy tubing could be considerably expanded if the price of those materials could be more realistic.

In connection with the methods for evaluating the merit of the various corrosion alleviation measures, it might be well for the beginner to consider the simultaneous use of iron analysis, coupons, tree inspections and tubing calipers until such time that a correlation between these can be established. It is not believed that sufficient experience now exists to specify the evaluation method or methods to use without first trying them all.

Question by G. A. Marsh, The Pure Oil Company, Research and Development Dept., Box 266, Winnetka, Illinois:

It was mentioned by the author that plastic coated and nickel plated tubing and rods are in use in some corrosive areas. What has been the experience of wearing of the coating or plating in pumping wells? Is corrosion accelerated where the coating is disrupted.? I k
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Author's Reply:

I know of no nickel-plated tubing in pumping wells. I understand that there are some nickel-plated rods being tested, but my company has none and has received no status reports on them.

Baked-on phenolic resins on rods and tubing will be damaged by wear in pumping wells. The coating is worn off of rod boxes in about two years and the boxes begin to pit. No internal inspections of tubing have been made in these wells but it is likely that some wear, possibly even through the coating, has occurred after three to four years of service. Coated tubing has not failed in three to four years; whereas, uncoated tubing lasts only about one year in these wells. In pumping wells, inhibitors are likely to prove more economical than special tubing materials.

Discussion on "CORROSION IN SULFUR PRO-DUCTION; THE USE OF AN ALLOY PRO-TECTIVE COATING," by Norman Hackerman and D. A. Shock, CORROSION 6, No. 6, 195-200 (1950) June.

Question by R. W. Flournoy, Corn Products Refining Company, Argo, Ill.:

In the corrosion tests in which steel test pieces in contact with elementary sulfur and water were rapidly corroded, were the corrosion products predominantly iron sulfides?

Question by Marc Darrin, Mutual Chemical Company of America, 1348 Block St., Baltimore 31, Md.:

I would like to ask Dr. Hackerman if he has identified the iron sulfide scale mentioned in his paper. Complex magnetic iron sulfide scales having a composition corresponding to Fe_6S_7 have been noted in pipe lines carrying sour crudes.

Question by S. J. Muery Jr., Freeport Sulphur Company, Port Sulphur, La.:

The use of aluminum alloys for sulfur production piping has been tried in the past with unsuccessful results being obtained. The 61ST alloy in pipe form was installed both for air lines in producing wells and for surface gathering lines between well and collecting station. In the air line application, failure of the aluminum pipe occurred after 20 days service whereas galvanized steel in this same application gave 29 days service before failure. Failure of the aluminum pipe was attributed both to the severe corrosive action of the well fluids on the aluminum and also to the galvanic action between the aluminum and the steel pipe into which it was installed concentrically. In the surface gathering line application 11/4-inch aluminum pipe was installed inside 4-inch aluminum pipe with the smaller pipe being a steam line and the well fluids being conducted in the annular space between the two pipes. Outside failure of the smaller pipe occurred, in one instance after 22 days service, with failure being attributed to a combination of corrosion and erosion. The 4-inch aluminum pipe was in service 148 days without failure, however, severe corrosion of the metal was noted. Thus from these tests it appears that the corrosion and erosion resistance of the aluminum alloy tested are not suitable for sulfur well piping.

Authors' Reply:

The insoluble corrosion products were iron sulfide according to a qualitative test in which scale scrapings were moistened with an acid and the gas evolved was determined to be H_2S .

We do not have the specific information which Mr. Darrin asked, although it would certainly be inter-

esting to try to make this identification.

The experience with 61ST alloy in pipe form which Mr. Muery describes shows that the aluminum alloy itself is not very resistant. It must be remembered that the coating we found to be very resistant contained: 2% aluminum, 2-5% magnesium, the remainder zinc. So far as we are aware this type of coating has not been given a full field test.

Discussion on "CATHODIC PROTECTION OF AN ACTIVE SHIP IN SEA WATER," by K. N. Barnard and G. L. Christie. Corrosion 6, No. 7, 232-234 (1950) July.

By L. P. Sudrabin, Electro Rustproofing Corpora-

tion, Box 178, Newark, N. J.:

What paint system used in conjunction with cathodic protection of the ship hull?

Authors' Reply:

No effort was made to use a paint system or surface preparation other than that currently in use on Canadian naval ships. Hull preparation was not extensive. The anti-corrosive was an iron oxide pigmented oil base paint. The anti-fouling paint was also oil base.

Question by F. L. LaQue, The International Nickel Company, 67 Wall St., New York 5, N. Y.:

1. Has there been any opportunity to observe effects of cathodic protection on the performance of the anti-fouling paints?

2. How much of the surface of the ship was "explored" by the reference electrode used for potential measurements where this electrode was located?

Authors' Reply:

1. Judging from experience with other ships there is no adverse effect of cathodic protection on the antifouling properties of the paint. Since this paper was written "New Liskeard" has been in drydock and was found to be in good condition from a fouling point of view. The behavior seemed to be quite normal for the type of paint used. Without a fairly extensive investigation however it is not safe to judge the effect on fouling. In Halifax we have a definite fouling season during the summer and a season of almost complete absence of fouling during the winter. This ship was painted in the spring and drydocked before the active season started. The paint system was therefore new during the time when fouling growth was heaviest and drydocking was

done before the next fouling season started. Under these conditions a minor decrease in the antifouling properties of the paint may not be noticed.

2. The hull of the ship was not "explored" with a reference electrode in this case. The "hull potential" was taken as a single value with respect to the reference electrode at a distance from the ship in electrically neutral water. This procedure has been established in previous work where potential surveys as well as single hull potential measurements were made. In the earlier work it was found that if the hull potential was above 800 mv. with respect to a silver-silver chloride electrode in sea water, there were no anodic areas on the hull. This has been further confirmed by the absence of rust on an inactive ship of the Algerine class and also on small active tugs that have been kept at this potential for over a year.

Question by Guy F. Williams, Dowell Incorporated, Kennedy Bldg., Tulsa, Okla.:

What was the composition of the magnesium used in the tests on the ship?

Authors' Reply:

The magnesium alloy used was of specification AZ63x. This contains about 6% aluminum, 3% zinc, with 0.2% (min.) manganese. The metal is very pure, having a maximum limit of 0.005% total Cu, Ni and Fe. Typical values are 0.001% Fe, less than 0.001% Cu and less than 0.001% Ni.

Discussion by Oliver Osborn, The Dow Chemical Company, Freeport, Texas.

We should like to confirm the excellent work of Mr. Christie that an active ship in sea water can be successfully cathodically protected. We have been making observations on two vessels operating in the harbor of Freeport, Texas, on which experimental magnesium anode installations have been made. One unit is a 30 ft. Marine Tractor (Sea Mule) on which protection has been maintained for the past 11 months and the other is a 45 ft. steel hull tug boat, on which protection has been maintained for 8 months. Surfaces were also coated with an antifouling vinyl system, and no unusual blistering of same has been observed. Protection as determined by solution potential with a Cu CuSO₄ electrode has been maintained even while the vessels were in motion. Applied current densities were in the range of 10 ma/sq. ft. or less.

We should like to point out that maintenance of an electrical connection throughout the life of the anode offers a definite problem due to the tendency of the magnesium to eat away at the point of contact with the connector. This problem was solved in our case by making the contact on a pipe core which had been cast directly into the magnesium anodes.

Authors' Reply:

Referring to the last paragraph of Mr. Osborn's comments, for the past three years we have used

steel cores cast in the anodes and the performance has been good. Recently copper cores were tried but were found to be unsatisfactory.

Discussion on "SOME ASPECTS OF THE COR-ROSION OF TIN PLATE BY PRUNES," by V. W. Vaurio, Corrosion 6, No. 8, 260-267 (1950) August.

By A. E. Teyral, Diamond Alkali Co., Painesville, Ohio.:

Was the tin plate studied given a protective treatment during manufacture such as the chromates?

Author's Reply:

The electrolytic tin plate had been given a chromate chemical treatment during manufacture. The hot dipped tin plate, however, was not chemically treated.

Question by E. A. Tice, The International Nickel Co., 67 Wall St., New York, N. Y.

Steel base C appeared to be more corrosion resistant than steel base B or A. Are these differences due to steel analysis? If so, what are the significant differences in composition?

Author's Reply:

Steels A, B, and C were not significantly different in composition as determined by chemical analysis. The different types of steels were produced by employing different manufacturing procedures.

Question by Clarence C. Harvey, Ethyl Corporation, Baton Rouge, Louisiana.

Were sprayed tin coatings tested?

Author's Reply:

Sprayed tin coatings were not tested in this work.

Discussion on "POTENTIALS SET UP BY THER-MAL GRADIENTS IN IRON IMMERSED IN NaCl SOLUTIONS," by Herbert H. Uhlig and Oscar F. Noss, Jr., Corrosion 6, No. 5, 140-143 (1950) May.

By G. A. Marsh, Pure Oil Company, Box 266, Winnetka, Illinois.

1. What is the cathodic reaction in the system described?

2. How is the curve of current vs. percent NaCl explained on basis of reduction of dissolved O_2 vs. cathodic reaction?

Authors' Reply:

1. The cathodic reaction when hot iron is coupled to cold iron in 3 percent sodium chloride is probably the same as the general cathodic reaction when iron corrodes in aerated natural waters. In other words, oxygen is reduced to hydroxyl ions.

2. The relation of current to percent NaCl described by Figure 4 relates to initial current only and does not include the situation for a differential temperature cell-short-circuited over longer periods of time (1 day tion of tration the rekind. eral reme

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ed es aie (1 day or longer). Work done subsequent to publication of this paper indicates that the current concentration relationship changes with time, illustrating the relative complexity of an irreversible cell of this kind. The data are still too few for an adequate general explanation of this cell, but it is hoped to remedy this sometime soon.

Discussion by N. E. Berry, Servel, Inc., Evansville, Indiana.

I wish to present some corrobating evidence that in the absence of oxygen the current falls to zero in a differential temperature cell of the type investigated by the authors in which iron electrodes are used. A similar result was obtained during the work on thermogalvanic corrosion in the Servel research laboratory. This may be contrasted with the results obtained on thermogalvanic copper cells where relatively high currents were obtained in the absence of oxygen and in the presence of appreciable concentration of copper ions.

In the latter case, the cathode reaction is the "plating out" or reduction of copper ion to metallic copper. In the cell investigated by the authors, the cathode reaction is almost certainly the reduction of oxygen. In the absence of oxygen this cathode reaction cannot be replaced by the plating reaction because of either the low concentration of iron ions in

essentially neutral solutions, or the known high overvoltage of the iron plating reaction.

This emphasized the difference between the irreversible differential temperature types of cells which depend upon the presence of oxygen (or perhaps hydrogen ion) and the essentially reversible "thermogalvanic" type of cell where the potential and current result from the differential temperature alone and where no over-all oxidation and reduction occurs.

Authors' Reply:

Dr. Berry's remarks distinguishing irreversible cells of the kind described in this paper, and reversible cells such as Cu in CuSO₄, are apropos in pointing out the greater complexity of the irreversible type cells. Whereas conditions approximating thermodynamic equilibrium are possible with thermogalvanic cells, similar conditions do not occur with the irreversible type, making interpretation of the latter more difficult. However, to better understand irreversible cells, one must first understand the reversible variety, many aspects of which require further exploration. It is hoped that this understanding will come soon, to be followed by more adequate knowledge of the irreversible cells, becaue most of the practical and interesting cases of differential temperature galvanic action are in the latter category.

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Topic of the Month

Effect of Barnacles and Corrosion on Metals And Alloys Suspended in Sea Water*

By STARR THAYER*

POLLOWING is a tabulation of observations made of several metals and alloys that have been submerged in sea water of Galveston Bay, Texas. These specimens were plates and rods and had been exposed to the water for 110 days. While this is insufficient time to evaluate the specimens as far as corrosion is concerned, it definitely shows the trend of each.

*Interim report on continuing tests being conducted by Grip-Tite
Manufacturing Company, Marshall, Texas to determine the most
suitable metals for pipe anchors to be used on structures submerged
in sea water.

* Consulting Engineer, Houston, Texas,

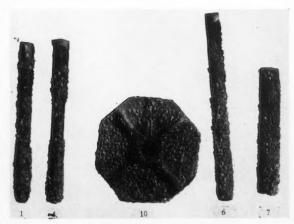


Figure 1—Metals submerged in seawater 110 days; before cleaning. Specimen identification: 1—Alloy of copper and malleable. 4—Alloy of copper and malleable. 10—Malleable iron. 6—Steel rod encased in copper. 7—Copper alloy steel rod.

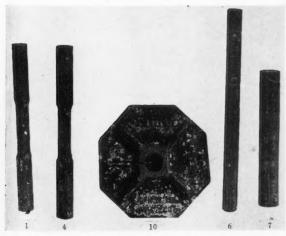


Figure 1A—Same metals as in Figure 1 after cleaning. Barnacles were removed by hand filing and wire brushing.

Specimen No. 1—An alloy of copper and malleable iron. It was covered completely with barnacles. Only evidence of corrosion was discoloration of the metal.

Specimen No. 4-Same as No. 1 but made by a different

company. Results were the same as No. 1.

Specimen No. 6—This is a steel rod encased in a copper envelope. The specimen was covered with barnacles but there was no evidence of corrosion. It had always been supposed barnacles would not live on copper surfaces. These barnacles may have been dead, but no area of the copper was free of barnacles.

Specimen No. 7—This is a copper alloy rod. It was covered with barnacles and corrosion had started.

Specimen No. 10—This is malleable iron. It was covered with barnacles and corrosion had started.

Specimen No. 11—This is a 10-10 steel plate. It was covered with barnacles and badly pitted from corrosion.

Specimen No. 12—This is a steel plate known as Mayasir. Results were the same as those on No. 11.

Specimen No. 14—This is a galvanized steel plate. There

Specimen No. 14—This is a galvanized steel plate. There were no barnacles on this plate, nor were there any signs of corrosion.

From the above observations it would seem that Nos. 1, 4, 6 and 14 would be best suited for service in sea water. The question as to how long the galvanizing will remain on No. 14 is not answered here.

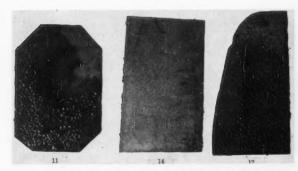


Figure 2—Metals submerged in sea water 110 days; before cleaning. Specimen identification: 11—10-10 steel plate. 14—Galvanized 10-10 steel plate. 12—Copper alloy steel plate.

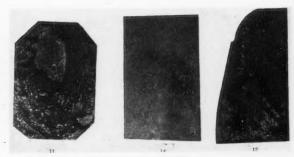


Figure 2A-Same metals as in Figure 2 after cleaning.



NACE News

Nine Meetings Are Scheduled at Chicago

Nine meetings have been scheduled by Chicago Section as follows:

All meetings are at Chicago Engineers Club, 314 S. Federal St. Fellowship Hour begins at 6 p.m. and dinner at

7 p. m. Sept. 19—Fellowship Hour, host Koppers Coke Co. Speakers, M. Van Loo, R. R. Bruhn and D. D. Laiderman of Sherwin-Williams Co. Subject: The Na-ture and Theory of Filiform Corrosion,

ture and Theory of Filiform Corrosion, accompanied by motion picture and slides. V. J. Payton, chairman.
Oct. 17—Fellowship Hour, host, Wright Chemical Co. Speakers: Four man panel to be selected. Subject: Corrosion of Electric and Gas Systems. F. M. Watkins, chairman.
Nov. 21—Fellowship Hour, host Amercoat Corp. Speaker: Vance N. Jenkins, Union Oil Co. of Calif., president NACE. Subject to be announced. C. A.

NACE. Subject to be announced. C. A.

Van Natta, chairman.

Dec. 19—Fellowship Hour, host,
Graver Tank & Mfg. Co., Inc. Entertainment: Motion picture and other subjects of general interest. H. L. O'Brien, chairman.

chairman.

Jan. 16, 1951—Fellowship Hour.
Speaker: N. E. Berry, Servel, Inc., vicepresident NACE. Subject to be announced. L. E. Nichols, chairman.
Feb. 20—Fellowship Hour. Speaker:
Nat A. Bailey, Wright Chemical Co.
Subject to be announced. J. Pat Casey,

chairman.

March 20-Fellowship Hour. Speaker: R. J. Kepfer, E. I. DuPont deNemours Co. Subject: Surface Preparation of Steel Plate. G. E. Seidel, chairman. April 17—Fellowship Hour. Speaker:

Mr. Colston, Hall Laboratories, Inc. Subject: The Corrosive Effects of Street De-Icing Salt. D. C. Glass, chairman. May 15—Fellowship Hour. Subject:

May 15-Fellowship Hour. Subject: Round table discussion and general business meeting. V. J. Payton, chairman.

General Conference Committee Convenes

The 1951 NACE Conference General Committee met at the Statler Hotel, New York City, July 12 to prepare gen-eral plans and policies for the conference program under chairmanship of L. B. Donovan. Mr. Donovan said the roster of subcommittees was complete with acceptance by M. Bermann, Brook-lyn Union Gas Company, of chairman-ship of the Transportation Committee. Many committees are fully staffed and detailed plans are under consideration.

The full committee made a tour of the Statler Hotel at which the confer-ence will be held March 13-16, 1951, and were greatly impressed with the facilities offered, it was reported by R. English, chairman of the publicity subcommittee.

Corrosion News Deadline: 10th of Month PRECEDING Date of Issue

Cleveland Section Meetings Planned

Eight meetings have been scheduled by Cleveland Section beginning with the September 27 dinner meeting during the Case Institute corrosion short course. Regular meeting date of the section is third Tuesday monthly. No meeting will be held in December.

Following is the schedule:

October 17, November 21 (Symposium on "Materials of Construction" by leading authorities has been planned for this session to be held at Hotel Carter, Cleveland); December, no meeting; January 16, February 20, March (Joint meeting with ASM. Dinner meeting at Tudor Arms Hotel, date unannounced), April 17 and May 15 (dinner meeting).

Brown to Address New York on Sept. 20

"Electrochemical Fundamentals of Corrosion," an address by R. H. Brown, chief of the Chemical Metallurgy Division of Aluminum Laboratories, Alumision of Aluminum Laboratories, Aluminum Company of America, New Kensington, Pa., and recipient of the NACE 1950 Whitney award is scheduled for the September 20 meeting of Metropolitan New York Section at Building Trades Employers' Association, 2 Park Ave., New York.

Permian Basin New Officers Are Named

New officers of the Permian Basin Section were elected at a meeting May 16 at the Gulf office building, Odessa, Texas. They are De Lasso Loos, Cool & Stillet Engineering Co., Midland, Texas, chairman; E. B. Ray, Republic Natural Gas Co., Midland, Texas, first vice-chairman; E. O. Kemper, Permian Enterprises, Inc., Odessa, Texas, second vice-chairman; C. O. Bundrant, The Western Company, Midland, Texas, secretary-treasurer.

2

Houston Section Will Meet September 12

L. G. Sharpe, Humble Pipe Line Co., will act as moderator for a panel discussion among four corrosion engineers of Houston Section on "Pipe Line Soil Corrosion Problems" which is expected to include pipe line coatings, cathodic protection of pipe lines, protection of the bottom side of tank bottoms and design factors, at the September 12 meeting of Houston Section. Charles Gribble, Metal Goods Corp., program chairman of the section, also has arranged to have Jess Neely, Rice Institute football head coach, discuss football possibilities for 1950 as a guest coffee speaker.

Dinner will be served at 7 p. m. at Guy Francis' Farnham House at the Farnham cut-off between South Shepherd and Greenbriar.

Underground Telephone Cables Is Topic at Los Angeles Meeting

Corrosion Problems on Underground "Corrosion Problems on Underground Telephone Cables" by David T. Jones of Pacific Telephone and Telegraph Company was the principal item at the June 21 meeting of Los Angeles Section at Rodger Young Auditorium, Los Angeles. A portion of the minutes of the Regional Management Committee was read in which it was recommended that formation of student sections be encouraged and also that a membership committee be formed to increase corporate membership.

Twenty-eight members and 14 guests attended the meeting.

Two more meetings by the section were scheduled for the remainder of 1950. First meeting, scheduled Septem-1950. First meeting, scheduled September 20 at Rodger Young Auditorium, is to have a talk, "Corrosion in Fish Canneries," by W. C. Stratton, Van Camp Sea Food Company; a talk on cathodic protection and a motion picture, "Drilling for Oil." The second meeting on November 15 at the same place has as its tentative program a talk on corrosion caused by salt or sea water and a motion picture on oil refining.

Jenkins Returns

Vance N. Jenkins, president of NACE, who has been ill and away from his work at Union Oil Company of California, Wilmington, Cal., returned to work on a part-time basis Monday, July 24.

During his illness work of the association was carried on by other officers of the association. His illness was reported in the July issue of CORROSION. Vacu Wat

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Vacuum Deaeration Solves California Mill Water Corrosion Problem for Dow Company

Control of corrosion by deaeration of mill water at the Pittsburg, California, plant of Dow Chemical Company was the topic of a talk June 14 by D. J. Pye of Research Department, Great Western Division, Dow Chemical Company, before the San Francisco Bay Area Section at Alouette Restaurant, San Francisco.

Principal points covered by Mr. Pye in his presentation "Corrosion Control by Deaeration of Mill Water" were:

The plant uses 7.5 million gallons of San Joaquin river water daily. Severe corrosion experienced in the all-steel tubular exchangers and pipe lines necessitated replacement of tubes in one major unit every 1½ to 2 years. It also was necessary to acid wash exchangers every three months to remove corrosion products which were seriously lowering thermal efficiency. Corrosion costs therefore were the sum of several items including equipment replacement, higher water consumption, loss of production and acid cleaning.

Oxygen Caused Damage

Brackish San Joaquin river water contains 7000 to 10,000 ppm salt and is near the oxygen saturation point; pH was 8.8 and carbonates were very low. Corrosion was believed to be the result of the oxygen content.

Two means of deaeration were considered: By vacuum and by chemical deoxygenation with sulfite. The vacuum method was adopted to treat the mill supply after a pilot operation proved

it satisfactory. Results of the vacuum deaeration were the same as that with sulfite treatment which was found to be considerably more expensive.

Equipment life has been increased five fold, fouling has virtually been eliminated. Savings per year through deaeration were estimated as follows:

Without Deaeration

Loss of Production	.\$7400
Acid Cleaning	. 3200
Tube Replacement	4500
Excess Water	
Total\$	19,200
With Deaeration	
With Deaeration Steam	\$3600
Steam	

Basis 5500

Total\$10,500

The vacuum deaerator is located between the mill supply pump and clarifier and consists of the deaerator tank, a pump, vacuum ejector and connecting piping. The 34-foot by 13-foot in diameter steel deaerator tank is reenforced to operate under 29 inches of vacuum. Inside the vessel are 24 feet of wooden slat packing over which the water cascades. Constant level is maintained by a controller. The water enters with 10 ppm oxygen and leaves with 0.25 ppm. In two years of operation the vessel has required no maintenance.

The Liquid Plastic that STOPS CORROSION PRUFCOAT COST OF CORROSION TO U.S. TO U.S. *Article in C. & E. News Vol. 27 — #39 against Acids,

Alkalis, Salt, Oil and Water

"Prufcoat proven superior to all other coatings we have tested" . . . writes one of America's largest chemical companies, after eight years' experience with Prufcoat. And this is just one of many reports on file testifying to the effectiveness of Prufcoat's famous liquid plastic formulations in controlling corrosion caused by chemical agents such as these:

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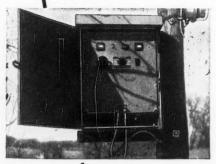
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Corrosion magazine seeks for publication notices of meetings of associations other than NACE which conduct corrosion investigations and research work. Members who know of such activities not reported in Corrosion are asked to notify Central Office so steps may be taken to publish the information.



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N.A.C.E. Member

San Francisco Section Hears W. Z. Friend's Discussion of Alloys for Process Industries

Wayne Z. Friend of the Corrosion Engineering Section of International Nickel Co., Inc., New York, addressed the May 22 meeting of San Francisco Bay Area Section at the University of California, Berkeley, on the topic, "Alloys for Process Industries."

Mr. Friend's presentation was a general discussion of successful applications of alloys in process industries as noted on his recent tour of the United States. Highlights of his talk were:

Ethanol Amine-Usually handled in all-steel equipment. Frequently boilers suffer severe corrosion. Stainless steels are suitable for handling amine solutions at 350 degrees F but not at 500 degrees F. Aluminum is attacked by MEA but not by a mixture of MEA and di-ethanol glyed. Monel handles amines satisfactorily, even at high temperatures.

Phosphate Plants - Type 316 ELC gives good service handling phosphoric acid at 50-60 degrees C.

Hydrochloric Acid-Type 316 satisfactory in mixture of HCl and gluconate at pH of 3.0.

Salt Water Service - 70-30 coppernickel containing 0.5 percent Fe has proved superior to other tube materials. If iron content is appreciably higher, pitting occurs.

Type 316 now is widely used for pumps and gives good service.

Steel Piling Protected

Cathodically-protected steel piling is to be used for a Long Beach, California, wharf. Monel will be used in the tidal zone with steel above and below.

High Temperature Services—Inconel is used in borax furnaces in vapor space

at 2100 degrees F. Performance is good unless sulfur is present. Sulfur produces intergranular attack at 1500 degrees and above. Inconel is most suitable alloy for lining combustion chambers of jet engines, giving excellent service to 2100 degrees F under oxidizing conditions. Inconel also is good in napthenic acid or fused caustic at 600 degrees F.

Nickel is used widely in the continuous manufacture of anhydrous caustic (evaporation process with tubular equipment). At 350-400 degrees F, chlorates decompose and become corrosive to nickel. A cast nickel containing 7 percent Si which does not seize or gall is used with no lubricant as bearing sleeves in pumping liquid bromine. Nickel also is used now to handle hydrocarbon-chloride mixtures up to 1000 degrees F and fluorine and HF up to 700 degrees C.

Tantalum-clad nickel tubing now is being developed to provide strength with corrosion resistance.

Titanium is completely resistant to nitric and other strong oxidizing acids at temperatures below and above atmos-pheric boiling point. Stainless steel is good only up to atmospheric boiling point. The effect of titanium in nickel alloys is being studied.

Aluminum is useful for handling ammonium nitrate and ammonia, whereas stainless steel is corroded by this mix-

Low Temperature Metals

Stainless steels, aluminum and 70-30 copper-nickel retain good physical properties, and the properties of 70-30 alloy improve at low temperatures.

Type 316 ELC vs Columbium Stabilized Type 318—Columbium stabilized is preferred if the material will be heated for long periods at 800 degrees F. Type 316 ELC with .003-.005C has good resistance to intergranular attack. Attempts now are being made to substitute tantalum for part of the columbium content in stabilized grades because of scarcity of the latter. The resulting tantalum alloy is more difficult to fabricate.

Thermal Conductivity With Clad Tubing—Various clad tube combinations of carbon steel, Type 304 steel, nickel, copper-nickel and copper were tested to determine thermal conductivity. Overall heat transfer for the clad tubes lay somewhere between the curves for the two alloys except with Type 304-clad tubes. The latter did not bond well and a low coefficient resulted.

Growing Interest In Exhibit Is Reported

Initial interest in exhibition arrangements for the 1951 NACE Conference to be held at the Statler Hotel, New York City, March 13-16 indicates demand for space will be high, it was announced by G. E. Seidel, chairman of the conference exhibition committee.

Detailed information is to be furnished in a brochure, together with contract forms, to be mailed to potential exhibitors prior to September 15.



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South Central Region Meeting Plans Are Given

Tentative arrangements for the 1950 South Central Region NACE meeting scheduled for Rice Hotel, Houston, Oc-tober 9-10 include sixteen papers, four reports on field and laboratory evidence of bimetallic corrosion to be given durming a production and general session Monday morning and two discussions and an open forum during a general and production session Monday afternoon, besides other items.

Two concurrent sessions will be held Monday morning and two concurrent sessions Monday afternoon. Single morning and evening sessions will be held

Tuesday.
R. B. McLaughlin, president of the Texas Pipe Line Company, Houston, will make the welcoming address at a will make the welcoming address at a luncheon and general business meeting Monday noon at the Rice Hotel. H. H. Anderson, vice-president of the Shell Pipe Line Corp., Houston, will make the keynote address preceding opening of the session on the economics of corrosion to be held Tuesday morning. Monday dinner will be at San Jacinto Inn, at San Jacinto Battleground, followed by an entertainment program. A barbene supper will be given at the Mayes cue supper will be given at the Mayes Bros. plant, Houston, Tuesday evening concluding the meeting.

Committees Will Meet

Technical Practices Committee meetings have been scheduled by TP-1—Corrosion of Oil and Gas Well Equipment, Ted S. Zajac, chairman; TP-3—Anodes for Use With Impressed Currents, Donald H. Bond, chairman; TP-18—Internal Corrosion of Facilities for the Storage and Transportation of Petroleum, L. G. Sharpe, chairman. Visitors as well as members of the committees are invited to attend meetings of the technical committees, all of which the technical committees, all of which are scheduled to be held Sunday,

TENTATIVE PROGRAM

Monday, October 9-Morning Session

Two concurrent sessions will be held as follows:

1. PIPE LINE SESSION

Pat H. Miller, Texas Eastern Transmission Corp., Shreveport, La., chairman.

9-9:20—Introduction and announcements by chairman, Pat H. Miller.

9:20-9:40—Preparation of Metals for Coating, A. J. Liebman, Dravo Corp., Pittsburgh, Pa.

9:40-10—Developments in Anticorrosive Coatings, G. R. Burnett, Bureau of Reclamation, Denver, Colo.

10-10:20—Experiences in Applying Various Combinations of Pipe Line Coatings, E. A. Koenig, Texas Eastern Transmission Corp., Shreve-

10:20-10:40—Effect of Pipe Diameter Expansion on Coating, M. M. Hel-ler, United Gas Pipe Line Co., Shreveport, La.

11-11:20-Twenty minute stretch.

11:20-11:45-Handling a Particular Corrosion Problem in Gas Distribution, A. D. Simpson, Jr., United Gas Corp., Houston, Texas.

2. PRODUCTION AND GENERAL SESSION

W. F. Rogers, Gulf Oil Corp., Houston, Texas, chairman.

The major subject of this session will be galvanic corrosion. Reports on field be galvanic corrosion. Reports on field and laboratory evidence of bimetallic corrosion will be given by the following: W. H. Edwards, The Texas Company, Bellaire, Texas; Jack P. Barrett, Stanolind Oil and Gas Co., Tulsa, Okla.; W. F. Oxford, Jr., Sun Oil Co., Beaumont, Texas, and W. H. Stewart, Sun Pipe Line Co., Beaumont, Texas; W. F. Rogers, Houston.

Monday Noon

Luncheon and general business meeting, Rice Hotel. Welcoming address by R. B. McLaughlin, president, Texas Pipe Line Co., Houston.

Monday, October 9-Afternoon Session

Two concurrent sessions will be held as

1. PIPE LINE SESSION

Pat H. Miller, chairman.

2-2:20—Corrosion of Underground Lead-Sheathed Power and Tele-phone Cables, L. C. Tuggle, Shell Oil Co., Houston, Texas.

2:20-2:40—Cathodic Protection Within an Oil Refinery (Tentative), Derk Holsteyn, Shell Refinery, Pasadena, Texas.

2:40-3—Corrosion Problems in Salt Water Operations, Jack Toler, Humble Oil & Ref. Co., New Orleans, La., and F. S. Bird, The California Co., New Orleans, La.

3-3:20-Twenty minute stretch.

3:20-4—Question and answer period.

2. GENERAL PRODUCTION SESSION

H. E. Waldrip, Gulf Oil Corp., Houston, chairman.

Discussion on Hydrogen Sulfide Con-densate Well Corrosion Problems by L. W. Vollmer, Gulf Research and Development Co., Pittsburgh, Pa.

burgh, Pa.
Discussion on Protective Coatings by
J. B. Scott, Phillips Chemical Company, Pasadena, Texas.
Use of Phosphate-Chromate Treatment
for the Protection of Metals Against
Pitting, Tuberculation and General Corrosion, by H. Lewis Kahler and Charles George, W. H. and L. D. Betz Co., Philadelphia, Pa.

Open Forum of questions and answers.
(Form on which questions may be submitted in advance will be sent members of South Central Region prior to conference.)

Monday Evening

Dinner at San Jacinto Inn, San Jacinto Battleground. Entertainment will follow the dinner.

Tuesday, October 10-Morning Session A combined session will be held on the economics of corrosion, H. H. An-

derson, chairman. Keynote address, H. H. Anderson, vice-president, Shell Pipe Line Co., Houston.

Economics of Condensate Well Corrosion, by T. S. Zajac, Shell Oil Co., Houston.

Houston.

Economics of Electrical Protection of Difficult Section of Pipe Line, by James F. Stephenson, Gulf Refining Co., Houston Pipe Line Div., Houston.

(Continued on Page 6)



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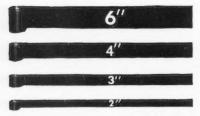
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Near Capacity Attendance is Forecast for Case Corrosion Short Course Sept. 25-29

Near capacity attendance at the Corrosion Short Course to be held September 25-29 at Case Institute of Technology, Cleveland, Ohio, is forecast by R. B. Hoxeng, Professorial Lecturer at Case and chairman of the Cleveland NACE Section, who is in charge of the course. The course is the second spon-sored by NACE through the association's educational committee of which Norman Hackerman of the University

of Texas, Austin, is chairman.
Cleveland Section of NACE is sponsoring a banquet at Tomlinson Hall,
Case Institute on the night of September 27, during the course. Short course participants will be special guests. N. E. Berry, Director of Research, Servel,

South Central -(Continued from Page 5)

Pipe Line Economics, by O. C. Mudd, Shell Pipe Line Corp., Houston. Economics of Corrosion in a Chemical

Plant, by C. C. Harvey, Ethyl Corp., Plant, by C. C. Harvey, Ethyl Corp., Baton Rouge, La. Protection of an Underground Water Tank, by Marshall E. Parker, Con-sulting Engineer, Houston.

Economics of Internally Coating Lines

in Place (author to be announced). Tuesday, October 10-Afternoon Session Combined session will make following tours:

Anode installations at Humble Pipe Line Co., Pierce Junction Station.

2. Coating operations at yards of Tube-Kote, Inc.

3. Exhibit of new equipment at United Gas Corp. yards.

4. Coating operations at yards of Mayes Bros

A barbecue supper will follow the inspection. This concluding feature will be held at the Mayes Bros. plant.

Inc., Evansville, Indiana, and vice-president of NACE will speak on "Corrosion Engineering; from Laboratory to Field." Special entertainment is planned by the Cleveland Section.

Lecturers have been selected on the basis of broad experience in their fields,

academic as well as industrial.

Registration fees for the course have been set as follows: Members of NACE, \$20. Non-members of NACE, \$27.50 (of this amount \$7.50 may be applied toward NACE membership). The fee covers all or any part of the course and must be paid in advance when application for registration is made. Registration is limited to 175

Case Institute can make arrangements for housing in hotel rooms near the campus and meals may be taken at the college cafeteria. Board and room can be arranged at a cost not to exceed \$7

> CORROSION SHORT COURSE PROGRAM

Monday, September 25-Registration. 10-12:30-Fundamentals of Corrosion.

2-4:30-Fundamentals of Corrosion, by R. B. Hoxeng, professorial lecturer, Research Associate in Chemistry, Case Institute of Technology, Cleveland, Ohio.

Tuesday, September 26

10-12:30—Types of Corrosion and Choice of Materials, by F. L. La-Que, head of Corrosion Engineering Section, The International Nickel Co., Inc., New York.

2-4:30—Electrolysis and Cathodic Protection, by H. A. Robinson, Assistant Director of Laboratory, Development Division, Magnesium Laboratories, The Dow Chemical Co., Midland, Mich.

(Continued on Page 7)





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This free bulletin describes the easiest, surest method of finding out if, where, and how badly electrolytic corrosion is attacking underground pipes and metallic structures.

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Practical Pipe Line Two-Day Course Is Held at Shreveport

The program for the Shreveport Section's Practical Pipe Line Corrosion Control Short Course, scheduled for September 7 and 8 at the Caddo Hotel Shreveport, Louisiana was as follows:

Thursday, September 7: 8 to 9 a.m., registration; 9 to 9:15 a.m., announcements, Joe Creevy, vice chairman and program chairman; 9:15 to 9:30 a.m., program chairman; 9:15 to 9:30 a.m., welcoming remarks, moderator for morning session, H. V. Beezley, chairman; 9:30 to 10 a.m., Introduction to Corrosion, Pat H. Miller and Paul E. Busch, instructors; discussion, 10 to 11 a.m., Some Causes of Corrosion, William Broome, instructor; discussion; 11 to 12 aoon, Coating as a Safeguard Against Corrosion, E. A. Koenig, instructor; discussion.

discussion.

12:15 to 1:30 p.m., luncheon, Tom L. Holcombe, master of ceremonies. 1:45 to 2:30 p.m., What is Cathodic Protection? (Demonstration), H. V. Beezley, instructor; discussion. 2:30 to 4 p.m., Practical Application of Cathodic Protection, M. J. Olive, coordinator; Pete Smith, O. C. Roddey and P. E. Busch, instructors. 4 to 4:30 p.m., Protection of Large Diameter Bare Pipe Line, T. B. McDonald, instructor. 4:30 to 5:30, Insulating Joints, Bonding and Test Leads as Safeguards against Corrosion, Wm. F. Levert and John Wise. 6 to 7:30 p.m., Fellowship Hour.

Friday, September 8: 8 to 9:30 a.m.,

Friday, September 8: 8 to 9:30 a.m., Instruments for Corrosion Control. Ex-Instruments for Corrosion Control. Exhibit of various instruments and explanation of their use. C. W. Evans, instructor. 9:30 to 12 noon, field trip, inspection of rectifier in operation, H. V. Beezley and Wm. Broome, instructors. Noon to 1:30 p.m., luncheon. 1:30 to 3 p.m., field trip, witness installation of galvanic anodes, Pete Smith and Wm. Broome, instructors. Broome, instructors.

Registration fee for the course was \$5, which included noon meals Thurs-day and Friday and field trip transpor-

The short course arrangements committee consisted of Pat H. Miller, chairman and H. V. Beezley, W. M. Belson, W. M. Broome, D. D. Dillingham; Dick Forester, Dick Graves, E. A. Koenig, Ed Mishou and Pete Smith.

Anodes Cause Bomb Scare

Considerable confusion, excitement and a lot of milling about that involved suspicions Red spies and saboteurs were lurking in the bushes was caused at Henrietta, Texas, when someone found 200 stored anodes formerly belonging to the Texas Company and came to the conclusion they were bombs. No little part of the suspicion aroused by the "strange objects" was a result of the fact the anodes were packed with backfill in bags labeled "Fresh Sweet Powdered Milk." Someone notified the FBI in Wishits Falls when one of the connection in Wichita Falls when one of the opened bags was found to contain two metal objects with wires protruding from the

The "bombs," on advice from a demolitions expert, were carried gingerly to the outskirts of the city and left under

guard. During the night, however, some hardy investigators discovered they could be sawed in half with impunity and also that they could be cut apart with an acetylene torch. Neither of these operations having produced an ex-

plosion, some of the apprehension about the "bombs" subsided. The Henrietta reporter for the Wichita Falls Record-News concluded his story with the observation the anodes "had been packed in a white powdered sub-stance to keep them from deteriorating" and that the unsettled question was who was to pay for the several packages that were opened during the bomb scare.

Near Capacity-

(Continued from Page 6)

Wednesday, September 27

10-12:30—Pertinent Fundamentals of Metallurgy, by Mars G. Fontana, head of Department of Metallurgy and Professor of Metallurgical Research at Engineering Experiment Station, Ohio State University, Columbus.

2-4:30—Use of Inhibitors and Chemical Treatment, by Aaron Wachter, Shell Development Company, Emeryville, Calif.

6:30 p.m.—Banquet, Tomlinson Hall, sponsored by Cleveland Section, NACE.

8 p. m.—Corrosion Engineering: From Laboratory to Field, by N. E. Berry, Director of Research, Servel, Inc., Evansville, Ind.

Thursday, September 28 10-12:30—Fundamentals of Protective Coatings, by William von Fischer, Head of Department of Chemistry and Chemical Engineering, Case In-

stitute of Technology.
2-4:30—Application of Protective Coatings by E. G. Bobaleck, Assistant Professor of Chemistry, Case Institute of Technology.

Friday, September 29

10-12:30-Designing to Prevent Corro-

sion, by R. B. Mears, Manager of Research Laboratory, Carnegie-Illinois Steel Corp., Pittsburgh, Pa. Applications for registration should be sent to R. B. Hoxeng, Case Institute of Technology, Cleveland 6, Ohio.



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Septemi

More Officers Named For '51 Symposia

G. G. Sward, National Paint, Varnish and Lacquer Association, 1500 Rhode Island Ave., N. W., Washington 5, D. C., has accepted a co-chairmanship on the Protective Coatings Symposium to be held at the 1951 NACE Conference in New York.

New York.

Officials to have charge of the Water Industry Symposium at the conference have been named as follows: R. R. Ashline, Electrolysis Engineer, Department of Water and Power, Box 3669, Terminal Annex, Los Angeles 54, California, chairman; A. Damiano, Hackensack Water Company, Weehawken, New Jersey, co-chairman; Thomas M. Riddick, Consulting Engineer, 369 149th St., New York 55, N. Y., co-chairman. R. L. Bullock, Interstate Oil Pipe Line Co., Tulsa, Okla., a co-chairman of the technical program, has general cognitechnical program, has general cognizance of the symposium.

Named to have control of arrangements for the Electrical and Communications Industries Symposium were H. W. Foelsch, Stalpic Coating Corp., 2310 S. Indiana Ave., Chicago 16, Ill., chairman; F. M. DeBeers, Jr., 20 North Wacker Drive, Chicago 6, Ill., co-chair-

Executive Committee Hears L. B. Donovan

General plans and policies of the 1951 NACE Conference general committee were presented by L. B. Donovan, chairman, at a meeting of the executive committee of the association's national board of directors August 5 at St. Louis. Arrangements for exhibition space, technical program and coordination of entertainment and conference functions were given approval tentatively.

BOOK REVIEWS

MATERIALS ENGINEERING OF METAL PRODUCTS. By Norman E. Woldman. Reinhold Publishing Co., 330 W. 42nd St., New York, N. Y. (1949). 583 pages, 6 x 9, cloth. \$10.

Advantages and disadvantages of most metals and alloys are given. Numerous tables of data on physical properties, performance statistics and illustrations are included. The book is divided into five sections: Materials for the electrical industries, materials for special and se-vere service, materials for light weight construction, materials for mechanical products, and materials testing.

All sections contain corrosion data, but considerable information on high temperature materials and corrosion-resistant materials is concentrated in the section on special and severe service. Included in the chapter on corrosion and its prevention are descriptions of corrosion reactions, the electromotive series, the galvanic series, rates of corro-sion and types of electrochemical corro-sion other than bi-metallic couple corrosion.

Cathodic protection, electroplated coatings, paint and surface treatment of steel, aluminum, magnesium, copper and copper alloys, zinc and zinc alloys are described under methods of protection. Included also is a table on the corrodibility of some common metals and alloys in several environments, such as atmospheric, aqueous, high temperatures gases, food products, acids, alkalies, salt solutions, hot sulfite liquor and crude oil.

The chapter on highly corrosion resistant materials devotes attention to nickel base alloys, nickel-moylbdenum-iron alloys, nickel-chromium-molybdenum-iron alloys and nickel clad and plated materials. Effects of various op-erations such as hot forging, heat-treating, cold forming, joining, machining, cleaning, pickling, degreasing, and scale

removal on corrosion are covered. Stainless steels and other corrosion resistant alloys are discussed in this chapter.

Some material on high temperature corrosion and oxidation by hot corrosive gases is included in the chapter on high temperature materials .-- MAI.

TP-2 Report Ready For Distribution Now

First report of Technical Practices Committee TP-2—Galvanic Anodes for Cathodic Protection, entitled "First Interim Report on Galvanic Anode Tests," designated NACE Publication 50-2, has been completed and now is ready for delivery. The report contains 53 pages of field data, anode operation curves, with a discussion of tests, procedures and results from field tests being conducted with aluminum, magnesium and zinc anodes in several types of backfill.

zinc anodes in several types of backfill. A digest of this report was published on Page 274 of the August, 1950 issue of Corrosion. Orders for copies of the report should be directed to Central Office, 919 Milam Building, Houston, Texas. Cost, postpaid is: NACE members, per copy, \$3; non-members, per copy, \$5.

NGAA Names Officers Of Corrosion Group

Elected at its recent semi-annual meeting at Fort Worth to head the Natural Gasoline Association of America's cor-Gasoline Association of America's corresion research project committee were: T. S. Zajac, Shell Oil Co., Houston, chairman; F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla., vice-chairman, Named to the committee's steering group, to direct its activities were T. S. Bacon, Lone Star Producing Co., Dalas; H. E. Waldrip, Gulf Oil Corp., 'Houston and P. P. Spafford, Stanolind Oil and Gas Co. All named are members of NACE and Technical Practices Com-

Plans are under way to publish the committee's reports in a single volume.

The Managing Editor of Corrosion magazine always is happy to see photographs considered suitable as subjects for the covers of the magazine. Address such photographs together with descriptive captions and release for the use to Central

NACE MEMBERS

IF You Change Addresses

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Corrosion Problems

Questions and answers for this heading should be submitted in duplicate if possible, addressed to "CORROSION PROBLEMS", National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas, Questions received at the address above above will be sent to E. A. Tice, The International Nickel Co., Inc., N. Y., who is acting editor of the page. All questions will become property of NACE. Questions and replies may or may not be published under this heading and may be answered either by mail directly to the person asking the information, or published under this heading, or both, at the discretion of the editorial staff. Answers to published questions res solicited, Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous if they request it.

- No. 55—How can decomposition of steam best be prevented inside high temperature (1000 to 1100 degrees F.) boiler tubes? Will chemical cleaning (acidizing) help this condition by removing oxide scale?
- No. 56—How can mercury corrosion be identified on aluminum or admiralty tubes?
- No. 57—At the present time, we are using 12-gauge steel tubes in the air preheaters of our cracking still furnaces. These tubes are 3 inches O.D. and 9 feet long. In five months' service we find that the top two feet, the cooler end, corrodes away due to the

presence of sulfur dioxide and trioxide in our flue gases. Some of the tubes have become plugged with iron sulfate, the plugging occurring just below the corroded end.

The temperature of the flue gases entering the preheater is about 100 degrees F and the outlet temperature, 700 degrees F. The fresh air enters at atmospheric temperature and leaves at 500 degrees F, the flow being counter current. Is there an alloy which will give us considerably longer preheater tube life? Is there an economical chemical means of neutralization of the corrosive gases or a coating which would protect the steel?

No. 58—How much damage to gas mains can result from telephone ground wire connected to service at meter loop

(a) When ground is used as ringing circuit?(b) When used as lightning ground

only?

- No. 59—Would a telephone ground interfere with insulating gas lines from water lines if grounded to the inlet of the gas line at one house and to the water line at the next house?
- No. 60—In connection with the use of steel piping for radiant heating of homes, have there been any reports of corrosion of such pipes where they are embedded in a concrete slab laid on the ground?
- No. 61—How can corrosion be stopped in the closed water cooling system described below: The system cools 13—1000-h.p.-

G.M.V. Cooper Bessemer engines. It's capacity is 45,855 gallons of water, circulated by 2—3600 G.P.M. pumps, cooled in Admiralty metal coils. The only opening in the system is a vent on the surge tank. Water make up is 270 gallons per day. Temperature of the water out of the engines is 160°F, and out of the coolers, about 144°F. A typical analysis of the water is as

follows:
Chromate 300 ppm.
Total Alkalinity 184 ppm.
Hardness 14 ppm.
pH 8.5
Rust in suspension.

No. 62—I would appreciate either a description of a method, or references to such, other than the "sessible drop method," for testing the comparative ability of oils to wet a steel surface.

a steel surface.

No. 63—What is known about the effect of solutions of sodium dichromate on Admiralty Brass and other nonferrous alloys, particularly from the standpoint of stress corrosion cracking?

We Want Your Answers To Corrosion Problems

Replies to questions under this heading are solicited by NACE. Tables, graphs and illustrations necessary for a full answer are welcomed. Address your answer to NACE Central Office, giving the question number. Early publication of answers is proposed.

Corrosive acid stored in tanks with stainless steel shells



The two acid feed surge tanks illustrated at the left were designed and purchased by the Chemical Construction Corporation of New York for installation at the Phillips Chemical Company's plant at Etter, Texas. They store nitric acid used in the manufacture of ammonium nitrate by neutralization with ammonia.

These two tanks, which are 20 ft. in diam. by 20 ft. high, are built of lightweight type 347 solid stainless steel plates with a carbon steel structure framing around them. Stainless steel was used because of the corrosive nature of the 60 per cent (by weight) nitric acid on ordinary steel.

We are equipped to fabricate and erect storage tanks and process equipment from stainless steel, aluminum, monel or other corrosion-resistant alloy steels and non-ferrous metals. Write our nearest office for further information or an estimate.

CHICAGO BRIDGE & IRON COMPANY

Atlanta 3 2137 Healey Building Birmingham 1 1552 North 50th Street Boston 10 1060—201 Devonshire Street Chicago 4 2119 McCormick Building Cleveland 15 2248 Guildhall Building

Philadelphia 3 1661-1700 Walnut St. Building Salt Lake City 4 563 West 17th South Street San Francisco 4 1572—200 Bush Street Seattle 1 1363 Henry Building Tulsa 3 1640 Hunt Building Vol.6

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Now—you simply "pull the zipper" on corrosion problems



Dresser ZIPCOAT for welded joints zips over weld area, fits closely to the pipe. 30" lengths.

NEW DRESSER ZIPCOATS* GIVE SURE PROTECTION, SUPERLATIVE DIELECTRIC STRENGTH

"As easy as zipping up a jacket" is what workmen say about Dresser's new ZIPCOATS. They install ZIPCOATS in 1/10 of the time it takes to coat a joint. You get protection that equals or exceeds that offered by the mill or vard-wrapped pipe.

And look at the hazards you avoid: there's no flame; no heating, hauling or messy application of hot stuff; no danger from fumes or burns.

Can be installed in any weather.

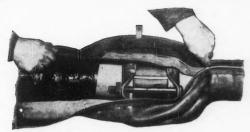
Write today for descriptive material and price list.

*Every ZIPCOAT complete with anaerobic microbiological corrosion inhibitor and cold sealing compound. ZIPCOAT is a trade mark of Dresser Manufacturing Division.

DRESSER

MANUFACTURING DIVISION

Headquarters: Bradford, Pa. (One of the Dresser Industries). Sales Offices: New York, Philadelphia, Chicago, Houston, San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ontario.



Dresser ZIPCOAT for couplings is easy to install over joint and pipe ends—all in one quick operation. Has bleeder valve to vent air during backfilling.

Dresser ZIPCOAT for insulating joints is made like the ZIPCOAT for welds, but in ten-foot lengths. Installing one on each side of an insulating joint that's protected with a ZIPCOAT for couplings gives ultimate protection. Eliminates costly boxing and filling with dope. Immediate trench backfill saves time.



New Dresser Bonding Method saves up to 50% of cost; materials preformed

Fast bonding, giving low resistance with preformed Dresser Bond and 5-second chemical welding method. Needs no special skill, no bulky equipment. Makes homogeneous weld area, eliminates surface contact variables. Compact kit of 50 preformed bonds includes all materials needed for installing.

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NEW MEMBERS

AND ADDRESS CHANGES

NEW MEMBERS

(Changes through July 27, 1950)

ALABAMA
MEGLEMRE, ROBERT W., Hercules Powder
Co., P. O. Box 190, Bessemer, Ala.

CALIFORNIA

AUBREY, RICHARD, Kaiser Steel Corp., P. O. Box 217, Fontana, Cal.
HALSTED, HAL F., Reed Halsted & Co., 2020
North Lake, Altadena, Cal.
SKAFTE, STANLEY F., Utility Appliance
Corp., 4851 S. Alameda, Los Angeles, Cal.

GEORGIA
LEE, BERTRAND EDWARD, SR., Lee Corrosion Enginering Co., 1341 Westmont Rd., S. W., Atlanta, Ga.

ILLINOIS

HOLTZSCHER, GEORGE A., JR., Granite City Steel Co., 20th & Madison Sts., Gran-ite City, Ill.

INDIANA CONRAD, HOWARD P., Northern Indiana Fuel & Light Co., Seventh & Cedar Sts.,

LOUISIANA

McCALLUM, WALTER C., JR., 85 Beauregard Ave., Maplewood, La. REEVES, FRANK E., Barnard & Burk, 314 Triad Bldg., Baton Rouge, La.

217 N. Detroit St.

MASSACHUSETTS
KELLEY, HOWARD M., Chemical Fire &
Rust Proofing Corp., 84½ Berkeley St.,
Boston, Mass.

WE, HARTLEY, United Fruit Co., 80 Federal St., Boston 10, Mass.

MARYLAND
KESSLER, KENNETH K., Baltimore & Ohio
R. R. Co., c/o Engineer of Tests, Baltimore, Md.

MICHIGAN LUTSCH, WILLIAM A., Dearborn Chemical Co., 3240 Book Tower, Detroit 26, Mich.

NEW YORK

BROWN, GORDON W., Cheesman Elliot Co., 639 Kent Ave., Brooklyn, N. Y.

DE LASKI, ROBERT D., W. A. Briggs Bitumen Co., 30 Church St., New York, N. Y.

GUENTHER, PAUL R., Nukem Products Co., 111 Colgate Ave., Buffalo, N. Y.

QUIMBY, W. S., The Texas Co., 135 E, 42nd St., New York 17, N. Y.

SHOUMATOFF, NICHOLAS, West Virginia Pulp & Paper Co., 230 Park Ave., New York 17, N. Y.

SIEGEL, EDWARD S., 5 Campus Place, Baldwin, N. Y.

Baldwin, N.

OHIO
CANNING, GEORGE R., Ohio Bell Telephone
Co., 750 Huron Rd., Cleveland, Ohio.

OKLAHOMA

BLACKMAN, BRUCE A., Dowell Inc., 524
Kennedy Bldg., Tulsa, Okla.

SARGENT, JOHN E., Sargent Engineering
Corp., 514 Oil Capitol Bldg., Tulsa, Okla.

PENNSYLVANIA
CATHCART, WALLACE P., Tank Lining
Corp., 1439 Oliver Bildg., Pittsburgh, Pa.
DOGGEN, JAMES E., #1 Bloomfield Ave.,
Apt. 7, Drexel Hill, Pa.
MORRISON, JOHN G., Rohm & Haas Co.,
5900 Richmond St., Philadelphia, Pa.
VANDERPOOL, HOWARD, Metallizing Engineering Co., 401 So. 16th St., Philadelphia
46 Pa.

RHODE ISLAND WHITE, WM. K., JR., Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

TEXAS

BRADLEY, BRYANT W., 1657 Castle Court.
Houston 6, Texas.
FARLEY, ELDEN R., Farley Co., Inc., 526
M&M Bldg., Houston, Texas.
SNYDER, KENNETH T., The Atlas Mineral
Products Co. of Texas, Inc., Box 252,
Houston 1, Texas.

FOREIGN
MARSHALL, GEORGE W., The Philip Carey
Co., Ltd., Lennoxville, Quebec, Canada.

CHANGES OF ADDRESS

(Old Address Follows New Address in Parenthesis)

CALIFORNIA

DIETZE, IRWIN CHARLES, Dept. of Water & Power, City of L. A., Box 3669, Terminaj Annex, Los Angeles 54, Cal. (Dept. of Water & Power, City of L. A., 141 South Martel Ave., Los Angeles 36, Cal.)

FRASER, JOHN P., 1220 El Cortola, Walnut Creek, Cal. (1845 Berryman St., Berkeley 3, Cal.)

SMALL, RICHARD B., California Research & Development Co., 200 Bush St., c/o F. W. Wyatt, San Francisco, Cal. (Standard Oil Co. of California, El Segundo, Cal.)

DISTRICT OF COLUMBIA

VAN ETTEN, FRANK M., Code 347. Bureau of Ships, Navy Dept., Washington 25, D. C. (Bureau of Ships, Navy Dept., 18th & Constitution, Washington 25, D. C.)

JOHNSON, THOMAS E., Illium Corp., Foot of Exchange, Freeport, Ill. (Burgess-Parr Co., Foot of Exchange, Freeport, Ill.)

MICHIGAN

BAKER, RALPH D., R. D. Baker Contractor,
Inc., Box 5155, Detroit 35, Mich. (R. D.
Baker Contractor, Inc., Box 187, Redford
Station, Detroit 19, Mich.)

MISSISPII AKERBERG, GEORGE E., 386 Raymond Road Gardens, Apt. 50, Jackson, Miss. (Metal Goods Corp., 432 Julia St., New Orleans,

(Continued on Page 14)



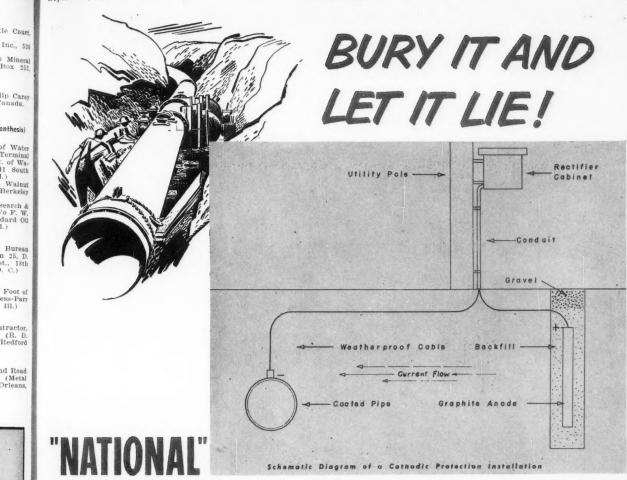
Telephone 2-5131

TULSA, OKLAHOMA

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GROUND ANODES DO THE REST-

"National" ground anodes provide the most practical and economical cathodic protection for buried pipe lines, tank farms, oil well casings, water mains, underground cables, ship hulls, and dozens of other products buried in earth or submerged in water. Here are the reasons:

Positive control in any weather; just change a tap on the rectifier to raise or lower current input.

- Perfect for use in high-resistance soils.
- Longest life of any anode material obtainable.
- Thoroughly tested and proved in service for more than 20 years.
- Complete and sure protection in sea water indefinitely.

Write to National Carbon Division for catalog section M-8500A, which gives all details on our ground anodes. Address Dept. CO.

NOW . . . double light at no extra cost!

Specify the new and improved "Eveready" 1050, flashlight battery and you get more than double the usable brilliant white light for critical uses than is available from any other flashlight battery National Carbon has ever made. The battery is leakproof...NO METAL CAN TO LEAK OR CORRODE!



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UNION CARBIDE AND CARBON CORPORATION

30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

Foreign Department: New York, U.S.A.

Septem

New Members -

(Continued from Page 12)

NEW JERSEY
PIKE, VERNON B., Bell Telephone Lab.,
Murray Hill, N. J. (Robert Pope, Bell
Telephone Lab., Murray Hill, N. J.)

NEW YORK

DANSER, J. W., American Telephone & Telegraph Co., 195 Broadway, New York 7, N. Y. (J. M. Standring, American Telephone & Telephone & Telegraph Co., 195 Broadway, New York 7, N. Y. (Josephone & Telegraph Co., 195 Broadway, New York 7, N. Y.)

PRINCE, ARTHUR E., Otis Elevator Co., 260 Eleventh Ave., New York 1, N. Y. (Joseph Mastroberte, Otis Elevator Co., 260 Eleventh Ave., New York 1, N. Y.)

PROSKOWITZ, SEYMOUR, 866 Hunts Point Ave., Bronx 59, N. Y. (2302 Wichita St., Houston 4, Texas.)

OHIO

FERGUS, D. J., 1206 Cleveland Hts. Blvd., Cleveland 21, Ohio. (Rickwell Corp., Bar-berton, Ohio.)

WERTZ, CYRIL J., 1016 Rushleigh Rd., Cleve-land 21, Ohio. (The Cleveland Union Ter-minals Co., 1016 Rushleigh Rd., Cleve-land 21, Ohio.)

OKLAHOMA

ADKINS, DAVID F., Cities Service Gas Co., P. O. Box 629, Ponca City, Okla. (Cities Service Gas Co., 212 N. Market St., Wichita, Kan.)

WIGHTA, Kan.)
NICKELL, J. F., Supt. of Pipe Line Dept.,
Wilcox Oil Co., P. O. Box 1440, Tulsa.
Okla. (Nickell, J. F., Supt. of Pipe Lines,
Wilcox Oil Co., P. O. Box 1440, Tulsa,
Okla.)

PENNSYLVANIA

BOWDEN, RAYMOND C., JR., Penn. & Braddock Ave., Pittsburgh 8, Pa. (327 Craft Ave., Pittsburgh 13, Pa.)

KEANEY, J. C., Industrial Metal Protectives, Inc., 1201 Banksville Rd., Pittsburgh 16, Pa. (Industrial Metal Protectives, Inc., 540 Lansdale Place, Pittsburgh 16, Pa.)

POPE, ROBERT, RD-3, Quakertown, Pa. (Pope, Robert, Bell Telephone Lab., Murray Hill, N. J.)

TEXAS

TEXAS

BELL, LEO A., The Dia-Log Co., P. O. Box
2426, Odessa, Texas. (The Dia-Log Co.,
P. O. Box 3043, Odessa, Texas.)

BROCK, CHELSEY L., JR., 5818 Southridge,
Houston 21, Texas. (508 Bremond St.,
Houston 6, Texas.)

BRUYERE, WM. H., Pan American Pipe Line
Co., 1413 Niels Esperson Bidg., Houston
2, Texas. (Pan American Pipe Line Co.,
12th Floor, Mellie Esperson Bidg., Houston 2, Texas.)

COLE, RALPH R., 3612 Potomac, Dallas 5.

12th Floor, Meine Esperson Datas, Rous-ton 2, Texas.)
COLE, RALPH R., 3612 Potomac, Dallas 5, Texas. (Paul G. Bentley Co., 3612 Poto-mac, Dallas 5, Texas.)
CONROY, JOHN H., P. O. Box 8188, Houston, Texas. (2508 Shakespeare Dr., Houston 5, Texas.)
CONS, ANSEL L., 250 E. Elmview Place, San Antonio 9, Texas. (452 Natalen, San Antonio, Texas.)

COONS, ANSEL L.,
San Antonio 9, Texas. (452 Nataien,
Antonio, Texas.)
FLANAGAN, J. C., Vice Pres. & Gen. Mgr.
United Gas Corp., Box 2628, Houston 1,
Texas. (Flanagan, J. C., Vice Pres. &
Asst. Gen. Mgr. United Gas Corp., Box
2628, Houston 1, Texas.)
HUSTEAD, B. G., East Texas Salt Water Disposal Co., P. O. Box 633, Kilgore, Texas.
(P. O. Box 633, Kilgore, Texas.)
LINGLE, ROBERT J., Room 305 Shell Bidg.,
Houston, Texas. (Room 309, Shell Bidg.,

LINGLE, ROBERT J., ROOM 309, Shell Bldg., Houston, Texas. (Room 309, Shell Bldg., Houston, Texas.) WADE, PAUL A., 207 E. 5th St., El Campo, Texas. (348 W. 23rd St., Houston 8, Texas.)

FOREIGN

BADRENA, FERNANDO, JR., P. O. Box 6666, Santurce, Puerto Rico. (Phosphate & Acid Works Div., Ochoa, Fertilizer Corp., Box 117, Hato Rey, Puerto Rico.)

THATCHER, FRED G., c/o Creole Petroleum Corp., Las Piedras Falcon, Venezuela, S. A. (c/o Creole Petroleum Corp., Re-fineria, Caripto, Monagas, Venezuela,

YOUNG, JAMES W., 1409 Premier Way, Cal-gary, Alberta, Canada. (Imperial Oil Co., 1409 Premier Way, Calgary, Alberta, Can-

NEW NACE CORPORATE MEMBERS

New corporate members added in the interval July 15-August 15, 1950, by the National Association of Corrosion Engineers are:

MOTOROLA, INC. Communications & Electronics Div. Chicago, Illinois

Eugene S. Goebel, Representative NATIONAL TUBE COMPANY Pittsburgh, Pennsylvania V. V. Kendall, Representative

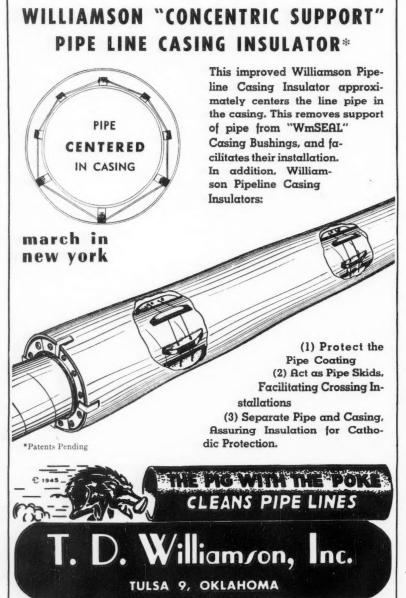
THE SYMINGTON-GOULD CORPORATION

Depew, New York
Peter F. Rossman, Representative

MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

Prof. Pierre Van Rysselberghe of the University of Oregon has sailed for Europe where he will spend the whole academic year mostly at Milan with Prof. R. Piontelli. He has been awarded the Fulbright grant as visiting lecturer.



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corrosion by

BITUMASTIC ENAMELS

Steel pipe lines, carrying gas and oil underground, need long-lasting protection against corrosion. And Koppers Bitumastic® Enamels provide that protection.

Koppers Bitumastic Enamels have been proved by performance. Under the most severe corrosive conditions . . . in all types of soil . . . under wide variations of temperature—these protective coatings have been giving good service for 30 to 40 years. And the knowledge gained by Koppers in protecting thousands of miles of pipe lines can be of value to your next pipe-line job.

There are good, sound reasons for Bitumastic's lasting protection. Processed from a base of coal-tar pitch, Koppers Bitumastic Enamels are impervious to moisture. They are chemically resistant to soil elements; they do not disintegrate with age; they maintain continuously high electrical resistance. Get in touch with your Koppers representative for details.





BITUMASTIC ENAMELS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 904T, Pittsburgh 19, Pa.

NEW PRODUCTS - Materials - Service - Literature

Pipeline Felt manufactured by GAMA Industries, Inc., 70 Pine Street, New York 5, N. Y., is described in a fourpage circular available on request from Middle West Coating and Supply, Daniel Bldg., Tulsa, Okla.

Odor-Less Dampcoat Enamel is recommended by manufacturers for appli-cation where damp surfaces prevail and where odors of ordinary paints would be objectionable. Further details may be had from Wilbur & Williams Co., Greenleaf and Leon St., Boston 15, Mass.

Stabilized Low Polymers of chlorotrifluoroethylene in the form of oils, grease and waxes are being produced in quantity by Halocarbon Products Corp., 2012 88th Street, North Bergen, N. J. Called Halocarbons and containing only carbon, fluorine and chlorine they are inert to corrosive agents including acids, alkalis, salts and oxidizing agents, manufacturers say. They are unaffected by prolonged heating in air at 480 degrees F. They may be used as bearing lubricants in high-temperature installations and as softeners for chlorofluorocarbon plastics

Nox-Rust Vapor Wrapper, an in-hibitor-impregnated wrapping material manufactured in several weights and specifications is useful for protecting metal parts from corrosion resulting from vapor. Further details can be ob-tained from Nox-Rust Chemical Corp., 2429 South Halstead St., Chicago 8, Ill.

Bakelite styrene spherical resin particles about 4-millionths of an inch in diameter form the base of improved waterproof, water-thinned, emulsion-type coatings being produced now by the Bakelite Division, Union Carbide and Carbon Corp., 122 East 42nd St., New York 17, N. Y. Paints and coatings based on the emulsions are resistant to moisture, soap, alkali, acid and chemical fumes as well as to dirt and abrasion, manufacturers claim. Produced in a range of colors, they can be applied by brush or roller.

Luster-on Utility 15, an inhibited zinc bright dip now is being offered by The Chemical Corp., 54 Waltham Ave., Springfield 9, Mass

Kel-F, a thermoplastic, can be moulded successfully to form a tough and flexible valve diaphragm which withstands chlorinated aliphatic and aromatic compounds, concentrated nitric, chromic, hydrofluoric and sulfuric acids and most solvents that attack rubber and synthetic diaphragm materials, according to Grinnel Company, Inc. Grinnel-Saunders valves may be cast of corrosion resistant alloys or lined with glass, lead or other materials to suit the material to be handled. Diaphragms can be used at pressures up to 100 psi and service temperatures vary with the material and pressure with a maximum of 225 degrees recommended at lower pressures. new diaphragms are not designed to be used under continuous vacuum condi-

Aluminum Alloy roots are being Aluminum Alloy roots are being bonded to airfoil sections of gas turbine stator blades by the Al-Fin process, a procedure owned by the Fairchild Engine and Airplant Corp., Farmingdale, L. I., New York. Wellworthy Pistons, Ltd., British licensees of the process, also are using it to produce aluminum. also are using it to produce aluminum

finned steel cylinder barrels, steel-backed aluminum bearings, bi-metallic pistons and other engine parts.

"Teflon" tetrafluorethylene resin now is being produced at a new unit of the Du Pont Company's plastic plant at Parkersburg, W. Va. Initially the plant will produce granular teflon only, but further expansion is under way for the manufacture of the new suspensoid consisting of minute particles of the plastic in a liquid from which wire extrusion compounds and corrosion-resistant finishes have been developed.

Nicrobraz, a heat and corrosion resistant alloy for brazing stainless steel has been developed by Wall Colmonoy Corp., 19345 John R. Street, Detroit, Mich. Joints equal in strength to the metal are claimed at 2000 degrees F. as is better corrosion resistance than the metal. It can be used to braze 300 and 400 series stainless, Inconel, Monel and other kinds of high alloy steels. Assembly to be brazed is prepared as for copper brazing, a joint clearance of .002-inch being best. Brazing is accomplished in pure dry hydrogen of —40 degrees F. dew point or below. Nicrobraz is held in place with Nicrobraz cement and will flow by capillary action through the joint when heated to 2050 degrees F.

A Corrosion Engineers Manual re-Products Corp., 111 Colgate Ave., Buffalo 20, N. Y., consisting of a thumbindexed, flat opening 8½ x 11-inch book divided into four sections: 1. Materials-Description of acid and alkali-proof cements, membranes and acid brick. 2. Technical and Shipping Data—Information needed for selection of type and quantities. 3. Tank and Sewer Data— Instructions on use of materials in these applications. 4. Acid-Proof Floors-Instructions on installation of long-life floors. Copies of the manual are available to members of NACE interested in acid and alkali resistant types of materials and installations covered.

Red Lead Vinyl and Coumarone Type Paints is the title of a 4-page technical data sheet on these types of coatings issued by the Red Lead Technical Committee of the Lead Industries Associa-tion, 420 Lexington Ave., New York 17, N. Y. It is designated Technical Letter No. 5. A description of the coating system and two formulas are included.

"All Under One Roof," a brochure describing the services of Sam Tour & Co., Inc., 44 Trinity Place, New York 6, N. Y., has been issued and is available for distribution.

Chemical Construction Materials of Atlas Mineral Products Co., Mertztown, Pa., and Houston, Texas, are detailed in General Bulletin MCC No. 1 recently issued by the company. It describes Atlas' corrosion-proof linings, cements, acidproof brick and tile, coatings and floors. Copies are available from 42 Walnut St., Mertztown, Pa.



the Silent Watchman

DIXIE TANK and BRIDGE CO.

3523 Lamar Ave.-P. O. Box 14, MEMPHIS 1, TENNESSEE

Complete Service for Elevated Water Tanks-

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32 Years Experience

KEEP THE SAFETY FACTOR IN YOUR TANK THE DIXIE WAY

By welding seams, pits and rivets which gives a riveted tank 15% more Safety Factor than it had when built. No rivets removed, water supply maintained while work is in progress.

On completely re-conditioned jobs, the painting is guaranteed for five years, repairs guaranteed for ten years, provided the tank is painted every five years. Yearly inspection, making all adjustments, if any, without additional cost.

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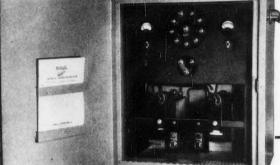
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RECTIFIERS

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CORROSION AWAY...

BUILT FOR LONG YEARS OF SERVICE

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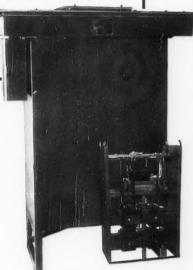
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Choice Seld-Cooled or Oil-Immersed No difference in cost

Choice Single-Phase or Three-Phase

Any combination D.C. Volts or D.C. Amp output.

WRITE WIRE OR CALL FOR COMPLETE DETAILS



OIL IMMERSED

GOOD-ALL ELECTRIC MFG. CO.

OGALLALA

PHONES 112 OR 113

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PERSONALS

J. H. Barnett, Jr., has been named general sales manager for Reilly Tar & Chemical Corp. with headquarters in Indianapolis, Ind. He formerly was in charge of the company's Chattanooga plant and was Southern District salesmanager. James D. Keith has been named plant manager of the Chattanooga plant.

Carl H. Baker, general consultant for Ebasco Services, Inc., has been elected a member of the company's board of

W. A. Lutsch has been named man-

ager of the Dearborn Chemical Company branch office in Detroit and the state of Michigan.

George M. Carvlin, vice president, Engineering and Construction Division Koppers Co., Inc., has been made assistant general manager of that division.

R. J. Driggs has been named Western District manager for the states of California, Oregon, Washington, Idaho, Nevada, Utah and Arizona coincident with the opening of a new warehouse at 103 S. Bayshore Highway, South San Francisco, Cal. by Dresser Mfg. Division, Bradford, Pa.

William H. Yeckley and Dr. Karl L. Fetters have been named assistants to

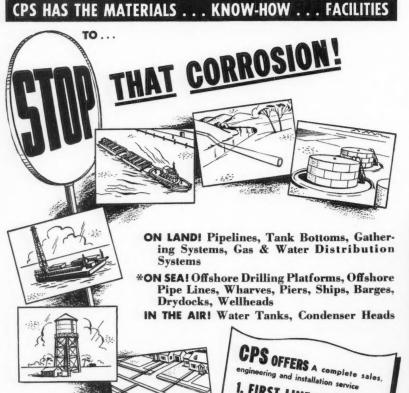
the vice-president in charge of operations by A. S. Glossbrenner, who recently was elected to the latter post at Youngstown Sheet and Tube Company, Youngs. town, Ohio.

C. W. Craig and C. E. Ericson have been appointed manager and comptroller respectively of the North Chicago, Ill branch of Atlas Powder Company's industrial finishes department.

E. R. Shepard, formerly with the National Bureau of Standards and the Corps of Engineers, Washington, D. C., from which latter organization he recently retired, has joined Hinchman Corp. of Detroit as technical associate. Mr. Shepard has had wide experience in the fields of soil corrosion, cathodic protection and geophysics. He is the author of many articles on stray current electrolysis, cathodic protection and other corrosion mitigation activities.

W. C. Snyder, Jr., has been named president of Freyn Engineering Company, a wholly-owned subsidiary of Koppers Co., with offices in Chicago, Ill. Mr. Snyder formerly was vice-president and manager of the Metallurgical Department of the Engineering and Construction Division of Koppers Com-

Raymond H. Hartigan has been appointed manager of the laboratory section of the central research department of Koppers Company, Inc. Gordon Black has been named assistant manager of the development section and Peter W. Sherwood manager of the engineering branch of the development section of the research department.



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Corrosion Abstracts

Describes the structure of oxide films formed on a thick copper test specimen at 200°C after different periods of exposure to the atmosphere. Mechanism of film for-

mation is explained. Data are tabulated. Includes diffraction patterns.—MA.

Gas-Metal Reactions, Andrew Drav-

Presents results of an investigation of

nieks and Hugh J. McDonald. Iron Age, 164, 78-82, 84-86 (1949), Aug. 25, Sept. 1.

above reactions where the products of interaction are nonvolatile and form scale on the surface of the metal. Utili-

zation of X-ray, electron diffraction, ra-dioactive tracer and electrical methods

in studying reaction products is described. Techniques for measuring gasmetal reaction rates are explored. In the

second and concluding installment, vari-ous continuous and discontinuous meas-

uring techniques for measuring reaction

rates - of which the micro-balance and

gas-volumetric methods are considered

the most versatile-are described and ap-

TESTING

Procedures for Testing the Corrosion Resistance of Meals. F. A. Champion. Ind. Chemist, 25, No. 295, 383-387 (1949),

Preparation of specimens, exposure

conditions, cleaning of corroded speci-

mens, analysis of products, assessment

of corrosion, corrosion/time curves. Although of a general nature, the paper re-fers also to aluminum and its alloys.—

Toxicity of Hull Paints. Simplified Analysis and Specification of Fouling Incrustations. M. G. Dechaux. Paper read to the Assoc. Technique Maritime & Aeronautique, 1949, June; J. Brit. Shipbuilding R. A., 4, No. 7, 338 (1949).

The correct assessment of an antifouling composition can only be statistical in nature, and a large number of

tests and a simplified analysis and system of notation are therefore required. The author suggests such a scheme which cov-

ers the relevant fouling organisms.—RPI.

Report of (ASTM) Committee A-5 on

The report contains recommendations

for the revision of the procedure of the Preece test (for zinc coatings), recommends the adoption of some tentative 19

Corrosion of Iron and Steel (and Zinc-Coated) Products. (ASTM Preprint No.

On Location Tests

2.2, 1.7, 4.2

3, 1949, 10 pp.)

praised. 71 ref.—BLR.

General

specifications as standard, and reviews the activities of the ASTM sub-commit-tees. Incorporated is the report of Sub-

Committee XV on field tests of wire and

wire products, which covers inspections

of exposed specimens made in 1948. Specimens have been exposed for ap-

proximately two years at two industrial, two sea-coast, and seven rural sites, and

materials included are chiefly bare steel and zinc-coated steel, but copper-cov-

ered and lead-coated steel, 12-14% chromium steel, and 18% chromium, 8%

nickel steel are also included. Specimens

were exposed as unfabricated wire, farm field fence, barbed wire, chain-link fence, and wire strand. Corrosion was assessed

by visual examination and loss of

strength. (Some weight-loss tests were

completed and reported in 1947.) Full

details of the condition of specimens re-

Florence Exposure Station of the Ital-

Pre-war tests had indicated that Flor-

ence with its rapid changes of temp. was a more suitable site than Naples or Tri-

este. Panels (30 x 50 cms.) are exposed

in single rows facing south, usually in-clined at 45°, but at 3° when special coatings, e.g., for the tops of vehicles, are under test. Finishing paints are

tested over the paint systems which will be used in practice. Varnishes are tested both on wood (oak, teak or pitch-pine)

and on green painted iron panels. The

methods of reporting and comparing results are described.—RPI.

PREVENTIVE MEASURES

Rubber Cocoons Oust Cellulose. Internat. Ind., 29, No. 9, 397 (1948).

A new process uses rubber latex in place of ethyl cellulose for cocoon pack-aging of metallic objects. 1.5% sodium

benzoate is included to prevent the corrosive activity of entrapped moisture.

—RPI.

Plastic Protective Coating. The Engineer, 186, No. 4848, 661 (1948) Dec. 24.

Clear Glass Products, Ltd., South-ampton, has introduced a protective coating known as "Avigel" plastic peel, for use on metal parts liable to become

corroded in transport or in storage. The transparent material is heated to a tem-

perature of 170°C. (338°F.), and a coating firmly adheres to the material dipped

in it. The protective material can be re-

peatedly used by remelting after being stripped from the component. A slight film of oil is exuded from the coating

Packaging

5.6, 5.8

ian State Railways for the Evaluation of

Paints and Varnishes. G. Balbi. Ind.

della Vernice, 3, No. 24, 64-9 (1949).

maining exposed are given.-MA.

Index to

CORROSION ABSTRACTS

8. Inhibitors, Passivators20

GENERAL

Kinetic Laws of Adsorption in the Special Case of Superficial Penetration. (In French.) Keith J. Laidler. Bulletin de la Societe Chimique de France, 1949,

D171-D176, Mar.-Apr.
Presents an equation approximating

the rate of adsorption and indicates the

conditions under which each of two mechanisms determine this rate. The

theory is applied to the adsorption of hydrogen by metals and to the formation of oxide films. 22 ref.—BLR.

1.8, 3.7
Chemical Reactions of Intermetallic Phases. I. Disintergration of the Intermetallic Compounds Ag. Al. and Mg. Pb. (In Russian.) E. E. Cherkashin, F. A. Derkach, and S. M. Przhevolotskaya. Zhurnal Obshchei Khimii (Journal of General Chemistra) 10, No. 81, 798-804 (1949)

eral Chemistry), 19, No. 81, 798-804 (1949)

metallic phases were investigated, in which metallic alloys in air under ordi-

nary conditions disintegrate into pow-der. Nature of the chemical processes occurring is established. Factors influ-

encing disintegration are studied. Kinetics of such reaction are indicated by

Cases of chemical reactions of inter-

6. MATERIALS OF CONSTRUCTION

1 GENERAL

2 TESTING

5. PREVENTIVE MEASURES

Fundamentals

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Septem

and transferred to the surface of the metal article it protects.-ALL.

Strippable Coating for Spray Booths and Product Protection Machinery. 56, No. 1, 191 (1949) Sept.

Chem-Peel, a strippable protective coating is a plastic emulsion applied either by spraying or dipping and imparts to treated surfaces a film of plastic which is easily removed by peeling. When applied to surfaces of dry spray booths, it acts as a barrier coating between booth walls and accumulated overspray. Objects plated or finished with an organic coating can be protected against corrosion and scratches. It is also useful

from scratches occurring during stamping or forming. Mfd. by Chemclean Products Corp.—INCO.

Treatment of Medium

5.7, 4.6, 8.9
Uses of a Deaerator. Marine Eng. Shipping Rev., 54, No. 5, 80-81 (1949)

The functions of a modern deaerator in a steam installation aboard a mod-ern ship are explained. Feed system corrosion is discussed.-INCO.

5.7, 7.1, 4.2 The Protection of Aero Engines in protecting articles with high finish Against Rust and the Deceptive Indi-

cations Given by Cobalt Chloride as Hygrometric Indicator. G. Jaubers Hygrometric Indicator. G. Jauber Compt. Rend., 228, 826-828 (1949). Chem. Abs., 43, 5516 (1949). In order to maintain a relative hu-

midity sufficiently low to prevent corrosion of engines in storage, SiO2 gel has been used as a moisture absorbent. CoCl₂, which is blue when anhydrous and rose-colored when hydrated, is sometimes added to the gel as an indicator of the degree of saturation of the gel with water. At ordinary temperatures com-mercial silica gel colored with CoCl. turns from blue to rose even though the silica gel has absorbed only 25-30% of the H₂O it can pick up. CoCl₂, being a better dessicant, actually reduces the efficiency of silica gel by clogging its pores. At saturation no commercial blue gel absorbed more than 25% of its weight in H₂O, whereas silica gels without CoCl2 absorb more than 60% of their weight in H2O.-INCO.

Inhibitors, Passivators

5.8, 4.4 Lubricating Oil Improvers. A. B. Boehm, Enjay Co. Paper before API Ann. Mtg., Chicago, Nov. 10, 1948. Petro. Ref. 27, No. 12, 131-135 (1948)

Growth and present proportions of the lubricating-oil additive business are reviewed here. Data on poor depressants show how winter-grade motor oils can be improved by the use of well dewaxed base stock with these additives. The mechanism of viscosity-index improvers is discussed and data presented show the effect on winter motor oils. In his comments on railroad Diesel lubrication, the author questions the soundness of practice of railroads restoring additives to reclaimed oil. In his comments on premium-type motor oils, the author states the use of additives combining oxidation control with effective detergency is necessary for worthwhile gain in performance. In the selection of motoroil additives, the author predicts there will be more emphasis on deposit control and less extremely low L-4 test bearing corrosion.-INCO.

5.8, 4.6, 5.6 Applications of Sodium Benzoate as Applications of Sodium Benzoate as a Corrosion Inhibitor. Chemical Research Laboratory (DSIR), Typescript, June, 1949, 4 pp. Chemical Research Laboratory (DSIR), Teddington, Middlesex.

A pamphlet discussing the use of sodium benzoate as an inhibitor in heat exchange systems, and for incorporation in packaging materials and temporary protectives.—BNF.

The Effect of Oxygen on Inhibition of Corrosion by Nitrite. M. Cohen, R. Pyke & P. Maurier. Paper before Electrochem. Soc., Chicago, Oct. 12-15, 1949. J. Electrochem. Soc., 96, No. 4, 254-261 (1949) Oct.

A study was made of the effects of the concentration of dissolved On and temperature on the rate of breakdown of sodium nitrite in the presence of steel and on the rate of corrosion of the steel. It was found that, at any given temperature, an increase in concentration of O2 decreased the amount of nitrite required for inhibition. At high temperatures and low O2 concentrations it was found that



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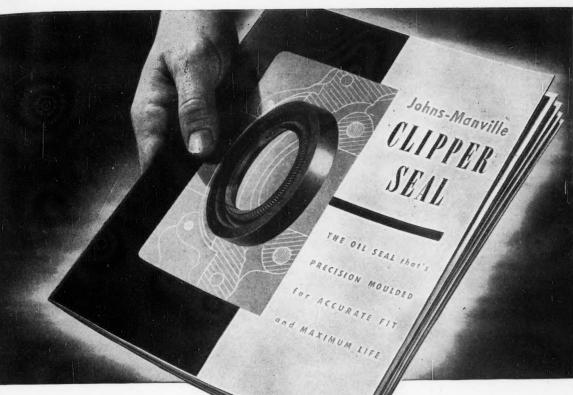
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PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y. —The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

WA—Journal, American Water Works Associ-ation. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.

Ave., New York 10, N. 17.

BL—Current Technical Literature, Bell Telephone
Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial
Institute Library. 505 King Ave., Columbus,

Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California, 2525

East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

London W±1, England.

M—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

-Marine Engineering, The Institute of Marine Engineers, 85/88 The Minories, London E. C.

Engineers, 85/88 The Minortes, Lanuaria,
3, England.
MR—Metals Review, American Society of Metals.
7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West
66th Place, Chicago 38, Illinois.

National Bureau of Standards. Supt. of Documents, U. S. Goy't Printing Office, Washington 25, D. C.

ington 25, D. C.

—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

Revue de Metallurgie, Paris, France, 5 Cite Pigalle, Paris (9e), France.

Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.
TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Porce Base, Dayton, Ohio.
TIME—Transactions of Institute of Marine Engineers. 35 The Minories, London EC 3, England.
UP—Universal Oil Products, 310 South Michigan

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

ing, well head and flowline surfaces. Due to lingering effect of the inhibitor, treatment of the well may be made at intervals of from 2-3 days to a week without a significant decrease in protection. Mfd. by Tretolite Co.—INCO.

5.8, 4.6, 5.6, 7.4

Metallic-Corrosion Inhibition. Development of the Sodium-Benzoate Process. Chem. Trade J., 124, 609 (1949) May 27.

A review of the current state of development of the use of sodium benzoate as an inhibitor of metal corrosion, as carried out by W. J. Bush & Co. is presented. To be effective the metal to be protected must be completely surrounded by sodium benzoate. For metals immersed in water or in solutions, the addition of from 1½ p.c. of sodium benzoate is effective; for impregnated wrappings, 2-5 p.c.; while for structural work, incorporation into undercoatings is being investigated. Sodium benzoate is particularly suitable for use in radiator systems and in industrial heat exchangers of all types. For protecting metal articles from corrosion during storage, the most convenient method of applying sodium benzoate is by incorporation in the wrap-ping material. The compound is a white crystalline powder, odorless, nontoxic and non-irritant. It is soluble at room temperatures to the extent of one part in two parts of water. The presence of chloride in the dispersing medium tends to reduce its corrosion-inhibitive properties.

The Use of Inhibitors for Controlling Metal Corrosion, Part II—Types of Inhibitors. G. T. Colgate. Metallurgia, 39, No. 231, 149-151 (1949) Jan.—ALL.

The Use of Inhibitors for Controlling Metal Corrosion-V. G. T. Colegate. Metallurgia, 39, No. 234, 316-318 (1949).

Inhibition of corrosion of light metals (aluminum, magnesium, and their alloys) is discussed.—MA.

Street Cleaning, Snow Removal-Letters to the Editor. M. L. Davis. Eng. News Record, 143, No. 16, 35-36 (1949) Oct. 20.

Results of 2-year tests with rust inhibitors have indicated that 2% admixture of sodium dichromate in salt is probably optimum mixture for rust inhibitors.—INCO.

5.8, 1.8, 6.1

The Role of Adsorption from Solution in Corrosion Inhibitor Action. N. Hackerman and H. R. Schmidt. Corrosion, 5, No. 7, 237-243 (1949) July.

Theories for the mechanism of organic inhibitors are reviewed, and the parts played by chemisorption and physical adsorption in inhibiting action are discussed. Results are given for both adsorption isotherm and electron diffrac-tion studies of steel treated with various inhibitors. 22 references.-BNF.

New Chemical Coolant Prevents Corrosion. Dr. K. F. Hager and M. Rosenthal. Amer. Mach, 93, No. 17, 87-89 (1949) Aug.

The properties of a new chemical corrosion-inhibiting coolant. Emulphor STH, are discussed. This compound can

although the rate of corrosion was appreciable the rate of nitrite breakdown was low. In some cases, a considerable time interval before the start of breakdown of nitrite was noted .- INCO.

5.8. 8.4. 2.2. 2.3

Field and Laboratory Tests of Sodium Chromates and Alkalies for Controlling Corrosion in Gas Condensate Wells. Part I. The Problem and a Resume of Results Obtained. C. K. Eilerts, R. V. Smith, F. G. Archer, L. M. Burman, F. Greene and H. C. Hamontre (Bur. Mines). (Paper, presented in part, NACE 1949 Conf. & Exhibition, Cincinnati (4/11-14/49); World Oil, 129, No. 3, 142-4+ (1949) July.

recommended procedure for controlling flow string corrosion in individual gas condensate wells by sodium chromate treatment is outlined, based on information obtained during 20 months of testing in a Cotton Valley field, La., well. Concentrations of about 50 ppm. of chromate in the water phase of the flowing fluid effectively stop corrosion, providing the effluent pH is maintained at about 7.7 by addition of sodium hydroxide. High chromate concentrations and low pH values enhance reduction by reservoir fluid constituents of the chromates to insoluble hydrous chromic oxide, which deposits on tubing walls and obstructs flow. Equipment used in treating the test well is schematically described. Two gas condensate fields averaged an added cost for chromate treatment of less than \$1.00/MMcf. of gas produced. Estimates of the composition and phase state of the fluid flowing in the tubing indicated at least five gal. of water/MMcf. were required for saturating the gas entering the tubing, i.e., during the flow of one MMcf. of gas, five gal. of water less than the volume of solution injected into the casinghead are available to flow upward through the lowest length of tubing

and carry dissolved treating compounds. Part II. Theoretical Considerations. Ibid. No. 5, 173-4+ (1949) Aug.

Charts useful in predicting the solubility of carbon dioxide in water and the

pH values of actual well water are presented, showing pure carbon dioxide solubilities in distilled water as a function of temperature and pressure, and the pH at 77°C. of aqueous solutions of chromates, sodium carbonate and bicarbonate, sodium hydroxide and phenol. The relation between the different chromate compounds and their contribution to the pH of solutions is indicated. In a flow stream of water having a pH between five and eight, any injected chromate becomes a mixture of mono-and bichromates. Acid chromates are more susceptible to reduction to insoluble oxides than are the basic chromates. Test results to be described (in subsequent articles) indicate the least reduction of chromates to occur when they are injected into the well at a rate just fast enough to provide a slight yellow color indicating an excess of chromate in the effluent water (28 references).

Part III. Maximum and Minimum Requirements of Sodium Chromate Determined, *Ibid*, 156+ (1949) Sept. Results of Bur. of Mines tests in the Cotton Valley Field are described, tabulated and charted.

Part IV. Tests of Mixtures of Sodium Chromate and Sodium Hydroxide, Ibid, 174+ (1949) Oct. Reports and discusses results of above.

5.8, 8.4

Corrosion Preventive. Chemical Eng.,

, No. 9, 165 (1949) Sept. Kontol 118 Stick, a stick form of Kontol corrosion preventive, is a cylinder 1½ in. in diameter by 18 in. long. The stick inhibitor is soluble in hydrocarbon solvents, and has a melting point of 175° F. It was developed in response to a demand for a conveniently usable inhibitor for gas and gas condensate wells in which tubing is packed or mudded-off, and when the addition of liquid inhibitors down the casing annulus would be of no purpose. The stick is applied by dropping into the tubing through a lubricator at the well head. On reaching the bottom of the tubing it slowly melts and disperses in the well fluids. During production of the well, a strongly adsorbed protective film forms on the tubaces. Due for, treatat inter-

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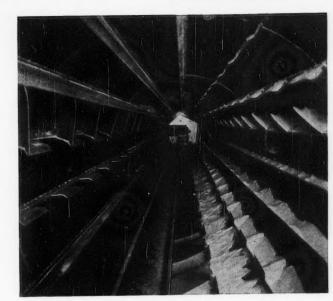
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be used in dilutions as low as 0.2% to prevent corrosion while retaining all the cooling effect of plain water. When compared with soluble and other cutting oils for rusting characteristics, the Emulphor STH in concentrations as low as 0.5% compared at least as well as the other oils at their recommended working concentrations, which are much higher than the recommended concentration for the Emulphor. When compared with soap emulsions, the new product shows much better corrosion inhibition. The com-pound is soluble in water, gasoline, and many oils and organic liquids, and possesses the valuable property of eliminating the fire hazard attendant upon the use of straight cutting oils.-TDD.

The Breakdown and Repair of Oxide Films on Iron. T. P. Hoar. Trans. Faraday Soc., 45, No. 7, 683-93 (1949) July.

The mechanism of breakdown and repair of oxide films on iron is examined with special reference to the influence of the film-rupturing anions chloride and perchlorate and the film-repairing anions carbonate, nitrate and chromate. Partial repair of the film due to electrolytic action, at the same time lowering the pH within the pores, may precede complete breakdown. The nature and production of pores are discussed, and an analogy between the electrolytic properties of oxide films and paint films pointed out. -ZDA.

5.8, 8.4 Corrosion Control. E. N. Jones, Consulting Engr., Pettus, Texas. Oil and Gas J., 48, No. 19, 107 (1949) Sept. 15.

Tests indicated better than 90% protection against corrosion was obtained in a gas well in West Tuleta field by in-jecting Kontol, a simipolar organic reagent, into the casing annulus. Daily dosages as small as 0.85 quarts were fed continuously by means of an old-style lubricator.—NALCO.

Protective Gasketing Material. Machine Design, 21, No. 7, 142-143 (1949), July. Commercial Motor, 1949, Aug. 12.

Specially compounded and impregnated felt containing zinc chromate as a corrosion inhibitor, Chrome Lock is a protective gasketing material featuring such properties as corrosion prevention, electrolysis prevention between dissimilar metals, flame resistance, non-oxidation, high compressibility and resistance to water and saline solutions. It has a pressure sensitive adhesive back for laying on all position surfaces. Variances in impregnation provide wide ranges of heat, cold, and pressure resistances. (Mfd. by Products Research Co.)

5.8, 5.6

Prevention of Corrosion by Vapour-Phase Inhibitors—Shell VPI 260. Nature (England), 164, No. 4162, 215 (1949) Aug. 6. Petro. Times, 53, 304 (1949) May

Vapor-phase inhibitors are being used in corrosion-prevention packaging. They are organic compounds, solid at ordinary temperatures, and produce an invisible protective film on the metal surface of an article within a closed container. Shell Chemicals, Ltd., London, has an-nounced a product for use in the oil in-dustry known as "Shell VPI 260" which is a white crystalline compound, odorless and non-toxic, a nitrite salt of an

Abstract Section Style Outlined

For ease in locating reference data, CORROSION uses a uniform style in its Abstract Section.

The abstracts first are broken down into major classifications of the more into major classifications of the more common types of corrosion literature. In each review the title of the article is presented in bold face type, followed by the author's name. The publication from which the article was abstracted is printed in italics and is abbreviated in most instances. Following this, in sequence, are the volume (bold face), number in the volume, pages, year and month of publication. In some instances a second reference will be listed in the same manner. This indicates that the article also was published or abstracted in another publication. A brief summary of the article follows the above information and it is concluded with an abbreviation indicating the source of the abstract and contributor. The meanings of these abbreviations usually are listed on the first page of the Abstract Section.

When seeking more detailed data

When seeking more detailed data about an abstract, best source of information is the publication in which the article appeared originally. (Listed in italics in the heading.) The contributor of the abstract also may be able to supply additional information. Addresses of most of these publications may be found in the reference section of most public libraries.

organic nitrogen base, applicable in powder form or in solution. An article is enclosed in the impregnated wrap, and the protective vapor permeates to every recess. Steel is particularly resistant to rust by traces of the inhibitor even when the moisture condenses. Other metals protected by VPI 260 are aluminum, duralumin, cast-iron and chromium plate. -ALL

5.8, 4.6 Rust Preventive. *Power*, 93, No. 8, 140 (1949) Aug.

Colorless, tasteless water compound, Borgana, is made from vegetable compound resulting from distillate of cedarlog waste. It is said to neutralize carbonates and organic growth and inhibit scale-forming elements of magnesium chloride and sodium chloride. Mfd. by Portland Shingle Co.-INCO.

5.8. 4.4. 8.1

Electrochemical Study of the Process of Metal Corrosion in Solutions of Ethylene Glycol. N. D. Romanov and M. A. Timonova. Zh. Fiz. Khim., 22, No. 2, 221-31 (1948).

Polarization curves obtained with copper and iron in a bath of ethylene glycol antifreeze solution indicate a substantial cathodic and a very low anodic polariza-The characteristic shape of the curve remains almost unchanged with progressively greater dilution within the concentration range between 55 and 20%. It is shown that inhibitors, specifically dextrin and a phosphate, have pre-dominantly an anodic protective action.

An Inhibitor of Pitting in 18-8. A. Sourdillon. Metal Prog., 56, No. 3, 356

(1949) Sept.

The use of sodium silicate (or silicate plus phosphate) as an inhibitor to prevent pitting corrosion in tank cans, used in the French railroad for milk transport, made of welded passivated 18-8 chromium-nickel austenitic steel is discussed. French reader is interested in hearing from American metallurgists

with definite knowledge of satisfactory industrial use of these inhiibtors in U. S —INCO.

5.8, 4.3, 8.1, 6.1 On the Effects of Inhibitors in Pick-ling (Corrosion of Iron). K. Wickert Arch. Metallkunde, 2, No. 4, 137-139 (1948).

A study was made of the corrosion of iron, using single or double electrodes, in hydrochloric acid with or without additions of Vogel's inhibitor. It is additions of Vogel's inhibitor. It is shown that: 1) in inhibitor-containing acid the calculated anodic metal loss is always smaller than the actual metal loss, 2) provided that the c.d. are equal the actual loss of metal at the anode is greater in inhibitor-free than in inhibitor-containing acid, 3) cathodic attack is appreciable in inhibitor-free acid, but almost non-existent in inhibitor-containing acid, 4) the inhibitor acts by decreasing the metal loss caused by secondary local elements but does not reduce that caused by primary local elements; this explains its action in reducing cathodic attack, which is generally due to secondary local elements, 5) under similar conditions, the corrosion of a single electrode is always greater than the corrosion of the cathode of twin electrodes, and 6) addition of an accelerator, such as so-dium chloride, causes an increase in corrosion, which is greater at the anode than at the cathode.-MA.

5.8. 4.6

Sodium Nitrite as an Inhibitor Against the Attack of Sea Water on Steel—Part II—The Addition of Other Inhibitors to Nitrite. D. Wyllie & C. N. Cheesman. J. Soc. Chem. Ind., 68, No. 7, 209-212

(1949) July.

Effect of mixing various inhibitors with sodium nitrite is described. The efficiency and probable mode of action of phosphates including metaphosphate. carbonate, sulfates and zinc salts are discussed. The radicals studied were those having insoluble ferric salts and reasonably soluble calcium and magnesium salts. Zinc salts were considered owing to possibility that their cathodic action might reinforce anodic action of nitrite. Sulfites were included in experiments owing to their ready reaction with dissolved O₂. 10 references.—INCO.

5.8. 8.4, 3.3 Further Field-Test Results on Use of Corrosion Inhibitors for Secondary Flood Waters. E. T. Hack, J. K. Barton, Quaker State Oil Refining Corp., & W. Howell, Hercules Powder Co. Oil & Gas J. 48, No. 18, 83+, (1949) Sept. 8.

Discussion of investigation of rosin amine D acetate and similar substances to determine their effect on growth of organisms in water systems. Pur-O-San, a quarternary ammonium salt supplied as a 10% solution in water and Arquad S, a soybean trimethyl ammonium chloride in paste form were the other substances tested. All three give satisfactory control of organic growth in most waters. Rosin amine D acetate and Pur-O-San were effective in controlling corrosion. A marked decrease in turbidity was evident with all three inhibitors.-INCO

Adsorption of Organic Corrosion Inhibitors on Iron and Steel Surfaces: Electron Diffraction Studies. N. Hackerman & H. R. Schmidt. J. Phys. Coll. Chem., 53, No. 5, 629-38 (1949). Polar materials adsorbed upon steel

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Data on "VIKOTE" Masonry Paint, courtesy The Malsanrock Company, P. O. Box 1031, Cincinnati 1, Ohio

Septen

were detected by electron diffraction methods. The firmness of adherence was assessed by determining the solvent required to remove the substance.—RPI.

5.8. 4.4

Lubricating Oil Additives. Part IV.
Oxidation Inhibitors and Detergents.
Part V. Dyes. Part VI. Anti-Foam
Agents. Part VII. Rust Preventatives. Part VIII. Present Status. V. A. Kali-chevsky. Petro. Ref., 28, 85-93; 125-128 (1949) Sept., Oct. Surveys the above, indicating both trade and chemical names. Includes ex-

tensive tabular lists of patented oxida-tion and corrosion inhibitors and metal derivatives of the detergent type. Name of compound or group of compounds is accompanied by patent numbers, date, and inventors' names.—BLR.

Surface Treatment

Cleaning. Degreasing Machine Handles Small Parts in Rotating Drums. Phillips Mfg. Co. Ind. Equip. News, 16, 100 (1948) Dec.—BL.

5.9, 5.3, 5.4

Protection of Ferrous Metals from Corrosion. J. A. D. Hutton. *Ind. Fin.* (Brit.), **1949**, 615-21, 691-8, 784-9.

After a short discussion of the mechanism of corrosion, various means of combating this, including controlled oxidation and the various commercial phosphatising treatments, are outlined and compared. Methods for applying metal coatings are briefly reviewed. The final article deals in very general terms with

vitreous enamels and the usual painting methods.-RPI.

Theory of Electrolytic Corrosion in Relation to Preparation for Paint. Ind. Fin. (Brit.), 1949, 357-8+.

In preparing a metal surface for paint the two properties to be sought are: 1) etching or roughening to provide a key for the paint, 2) surface-insulating to prevent electrochemical action. To attain these properties several processes may be employed, e.g., galvanizing, Bonderizing, phosphatizing, etc.—RPI.

The Role Phosphatization Plays in Protection by Paint. E. Jaudon. Peint. Pig. Vernis, 25, No. 6, 224-6 (1949).

A phosphate coating considerably improves the durability of a paint system applied to steel test panels. The thickness of the phosphate layer has a bearing on the rate of corrosion.-RPI.

5.9, 5.4

Controlled Rusting of Iron as a Preliminary to Painting. H. Ketterl. Metalloberflache, 3, No. 3, 72 (1949); Electroplating, 3, No. 1, 27 (1949).

The following procedure, which was developed originally for the treatment of black sheet for food cans, is claimed to be simple and particularly suitable as a treatment before the application of oil-free (synthetic) paints: 1) pickle, 2) rinse, 3) suspend in moist air until uni-formly rusted, and 4) stop further rust-ing by heating and drying at 200° C. A golden brown to dark brown or even black coating is produced according to

the nature of the pickle. Some impor-tance attaches to the type of pickle, which must be suited to the composition of the iron, but details are not given.

—RPI.

5.9, 2.3, 6.2

Anodic Oxidation of Ferrochromium in a Solution of Sodium Carbonate. (In French.) Jean Besson and Chu Yung-Choo. Comptes Rendus (France), 229, 207-209 (1949) July 18.

The above was investigated for two specimens of compositions 29.2 and 32.4 iron and 60.0 and 63.9% chromium. Anodic oxidation resulted in formation of chromate under the conditions of experiment, followed by formation of a more or less adherent film of iron oxide on the anode.-BLR.

5.9, 8.8

Simplified Methods of Cleaning Metals for Plating. J. L. Bleiweis. Mat. & Meth., 30, 74-77 (1949) Sept.—BL.

5.9, 5.3, 5.4, 6.7
 Metal Finishing. A. Bregman. Annual review article. *Iron Age*, 163, 274-281 (1949) Jan. 6.—BL.

5.9, 7.10, 5.4

Oxyacetylene Flame Cleaning of Metal Bridges. Can. Transportation, 1948, July; Bull. Doc. Tech, S.N.C.F., 1948, No. 11; Trav. Peint., 4, No. 2, 64 (1949).

Canadian tests showed that a bridge could be painted in 6 weeks using flame cleaning, compared with 12 weeks using sand blasting or 14 weeks using grinders and wire brushes. Since the steel-work is painted while still warm after flamecleaning no moisture is trapped under

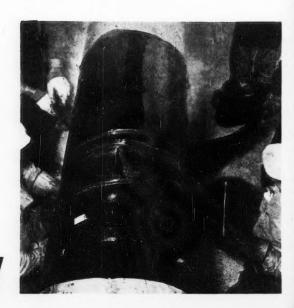
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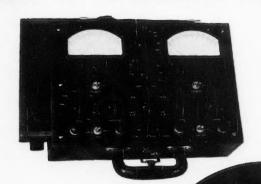
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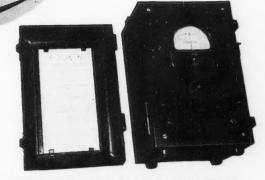
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the paint and the durability of the paint is improved; it is estimated that a 20% saving in paint results. The method of operation is to "brush" the surface with a flame at 650° C, which vaporizes adsorbed water and almost instantaneously detaches old paint and rust.—MA.

5.9

Chemical Rust Remover. Chem. Age,

60, 890 (1949) June 18.

A German process for removing rust by chemical means has been developed and used to remove rust from ships' hulls, steel vaults and bridges in Germany. It is claimed that the chemical (not identified) mixes with rust without eating into the surface of the metal and protects it from further deterioration after rust removal. Small articles are immersed in the chemical bath, followed by rinsing and further chemical treatment to make the metal impervious to rusting again. Paint, oil and gases are able to adhere to the surface thus imparted to the metal. A chemical paste is applied to larger surfaces, followed by treatment similar to that for dipped

articles. 5.9, 6.4

Cleaning Aluminum for Surface Treatment. G. C. Close. Light Metal Age, 7, 6-7, + (1949) Aug.—BL.

50 54

Increasing the Adhesiveness of Baked Lacquer Coatings on Strip Steel and Thin Sheets. (In German.) F. Eisenstecken. Archiv fur Metallkunde, 2, No. 8, 256-258 (1948).

Reports results of a study on the effects of cleaning and pretreatment of the metal surface on the adhesiveness of

lacquer coatings and their behavior. Results are illustrated.—BLR.

5.9

Protective Treatments for Aluminum —I & II. J. L. Bleiweis. Amer. Machinist, 93, No. 20, 149, 151 (1949) Oct. 6. Purpose, nature of coatings, and treat-

ment procedure, with comments, Alrok process, Alumilite processes and anodiz-

ing are discussed.—INCO.

5.9

Amorphous Phosphate Coatings for Protection of Aluminum Alloys and for Paint Adhesion. A. Douty and F. P. Spruance, Jr. Prod. Fin., 13, No. 11, 58

(1949) Aug.

This paper was presented by Mr. Douty at the American Electroplaters' Society's 36th Annual Convention in Milwaukee June 27 to 30, 1949. The authors reviewed several treatments used for the protection against corrosion of both unpainted and painted aluminum. The Alodine process for preventing both surface and underfilm corrosion was described. The process is as follows: alkaliclean, rinse, Alodine dip or spray—15 seconds to 3 minutes (dry without rinsing if surface is not to be painted), rinse in dilute phosphoric or chromic acid held at 100 to 130° F. (38-54° C.), dry. By means of slides the authors illustrated the results obtained by salt spray tests on a number of painted and unpainted specimens. (Authors' summary.)—ALL.

50

The Cleaning of Metals. Part IV. Emulsifiable Cleaners. R. Groves. Metallurgia, 37, 217-219 (1948) Feb.

Emulsifiable cleaners do not corrode or tarnish most metals and have a wide range of application. They are based on a penetrating and dispersing agent capable of being dissolved in oil. The agent is compounded with paraffin or a safety solvent in the ratio of 1:10 and this solution is applied by spraying or dipping. About half a minute is commonly required for cleaning, followed by rinsing in a cold-water spray. The dirt particles are suspended in the emulsion formed by the solution with the water.

The solution does not ignite until its flash-point is reached, hence use at room temperature involves little risk. It produces physically clean surfaces and, in contrast to the chemically clean surfaces left after solvent degreasing, requires no wiping or alkaline cleaning unless the surface is to be plated or coated with a viterous enamel. Since the surface is not passivated, this method of cleaning is especially advantageous for Bonderizing. It is also well suited for removing the carbon dirt from steel and is more economical than hand wiping or brushing for polished, buffed, heavily oiled, lubricated, drawn and stamped parts. It is not applicable to parts which nest or lock together or which have deep re-cesses, unless the cleaner is used in a washing machine which ensures full effi-ciency of the cleaning solution and thorough drainage of parts.

Washing equipment, whether a plain tank or a complicated apparatus, must be chosen carefully, considering the form of the parts to be cleaned, their dimensions, the degree of damage to which they are exposed if handled carelessly, the quantity to be treated, i.e., the number of parts per hour, and the method of



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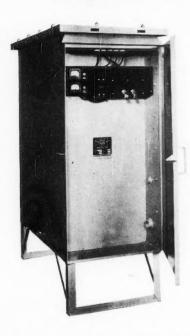
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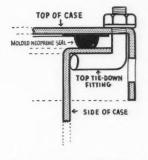
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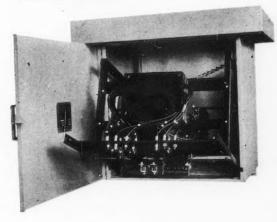


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heating if a cleaning solution other than an emulsifiable type is used.

In previous reports of this series, the author discusses the choice of cleaning process and cleaning agent, alkaline cleaners and various cleaning operations. (Metallurgia, 37, 40-42, 100-102, 147-149 (1948).—PDA.

50

Phosphate Processes for Iron and Steel with Special Reference to Rust-Proofing. E. E. Halls. Metallurgia, 40, No. 237, 159-63 (1949) July.

Although mainly concerned with the

Although mainly concerned with the treatment of iron and steel surfaces, the article mentions the fact that some processes are also applicable to zinc and zinc alloys—a great convenience when a fabricated assembly embodies several differ-

ent metals. Other applications of the phosphating processes are to assist drawing operations in pressing, and to impart wear resistance at intermetallic contacts.—ZDA.

5.9

Latest Developments in Phosphate Coating Methods and Technique. H. A. Holden. J. Electrodepos. Tech. Soc., 1949, No. 24, 111-28.

A review of progress during the last five years. The most effective method of cleaning surfaces utilizes a hot alkali spray, as this results in smaller and more uniform phosphate crystal formation. New methods of application and the use of new accelerators, e.g., chlorates, are mentioned. For coating iron and steel surfaces, the zinc flash Bonder-

izing process has been developed, and results of tests indicate its marked superiority to Bonderizing alone and to simple trichlorethylene vapor degreasing. The process involves the electrodeposition of a thin layer of zinc followed by phosphating and painting. Methods of treating zinc and aluminum surfaces are followed by sections on the use of phosphating to facilitate cold working and as an aid to lubrication. Twenty references and a discussion conclude the paper.—ZDA.

5.9, 5.4

How to Paint the Product. I. H. E. Linsley. *Machinist* (Eur. Edn.), **92**, No. 29, 941-956 (1949).

L. fully describes the preparation of the surface of a large number of metals for painting, the selection of the paint and its preparation, spray painting and its difficulties, and electrostatic spraying.—MA.

5.9, 5.4, 7.2, 8.8

Preparation of Pipe Surface for Bitumen Coating During Reconditioning, O. C. Mudd, Shell Pipe Line Corp. (Paper, NACE), 1949 Conf., Cincinnati, 4/11-14/49. Corrosion, 6, 19-21 (1950).

Instead of sandblasting rust from stee

Instead of sandblasting rust from steel structures, such as pipes and tanks, and then following up by a primer coat of other rust mixed with a paint vehicle, it is suggested that the tightly adhering siliceous material be left on the pipe and chemically treated to drive out moisture and saturate the surface with appropriate inhibitors or priming solutions. A dilute primer applied to machine-cleaned pipe improved the bond of the hot asphalt and caused fewer holidays than is usual with sandblasted pipe, because the moisture from the tightly adhering corrosion products had been removed. Chemicals, such as amines, may be added to remove or exclude moisture from the metal surfaces. Various means of cleaning pipe, such as sandblasting, flame cleaning and high-frequency electric induction heating are discussed.

5.9. 6.1

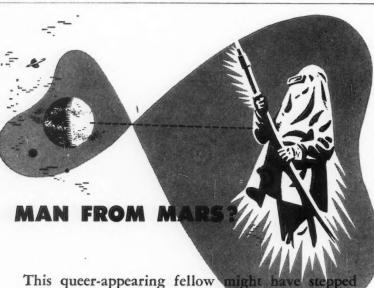
Pickling of Acid and Heat Resisting Steels, I. P. Sinitsyn. Stal, 8, No. 6, 540-542 (1948).

Report on a new pickling process using only inexpensive chemicals and especially developed for acid and heat resisting (nickel-chromium) stainless steels, various low tungsten high speed steels and high silicon steels, difficult to pickle. Principle of process, results of preliminary experiments, data on composition of bath and on operation of pickling line, various pickling defects and how to overcome them, factors favoring pitting, how to adjust the pickling bath and advantages of new process are discussed.—INCO.

5.9, 2.3, 5.8, 6.2

Surface Treatment and Finishing of Light Metals—Part 2—Corrosion and Protection of Aluminum and Its Alloys. S. Wernick. Sheet Metal Ind. (England). 26, No. 266, 1289-1296 (1949) June.

The two chief classes of corrosion tests are weather-exposure tests and accelerated laboratory tests. In the former, results are obtained by determining loss in tensile strength and elongation of groups of the tension specimens and computing their variation from similar specimens stored indoors over the same period. These results of visual examina-



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tion and weight changes of specimens are recorded a) without removing the are recorded a) without removing the corrosion products, and b) by cleaning and measuring loss in weight. Depth of attack is determined by a micrometer depth gauge, or by sectioning, polishing and measuring with a microscope fitted with a micrometer eyepiece. Laboratory tests are of two types: a) accelerated corrosion tests, in which one or more corrosive influences is intensified to a corrosive influences is intensified to a degree so that the corrosion period is degree so that the corrosion period is reduced considerably, and b) physical or electrochemical tests designed to predict the behavior of the material from the properties. Common tests for aluminum include immersion of the specimen in hydrogen chloride to determine the rate of hydrogen evolution, subjection of aluminum to salt-spray, and testing in alternate wet-and-dry immersion appa-ratus. Salt-spray tests are useful for predicting comparative values for corrodibility under marine conditions. Of some importance are the several physical tests for measuring the potential drop of the

corrosion. To insure maximum corrosion resistance, the following general conditions must be assured: 1) Correct choice of alloy in relation to service conditions—with special regard to purity in composition and strict material control. 2) Careful control of casting and heat treatment. 3) Correct design to avoid formation of concentration cells or contact with dis-similar metals. 4) Correct choice of fin-ish in relation to the metal or alloy.

metal in solution, and for testing stress-

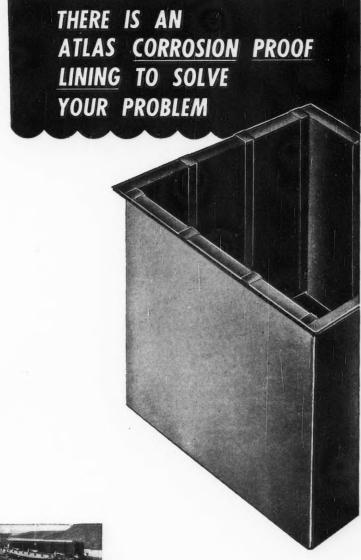
Corrosion inhibitors, either anodic or cathodic, to produce insoluble reaction products or alternatively to be adsorbed by the metal surface are in widespread use. Chromate inhibitors, including zinc, barium and strontium are employed with aluminum. Other important inhibitors include soluble chromates and dichromates; borates, phosphates, nitrates, chlorates, nitrites, lactates, acetates, organic colloids and nitrogenous inhibitors.

The oxide film which forms on aluminum when exposed to the atmosphere is a natural protection against normal corrosive attack. Chemical or anodic treatment of aluminum will produce thicker oxide films than will naturally occur and thereby increase corrosion protection. The corrosion testing of coated aluminum alloys is similar to those used on untreated metals.—ALL.

5.9, 2.3, 6.2

Surface Treatment and the Finishing of Light Metals: Part 4-Chemical Cleaning and Pre-Treatment Processes. S. Wernick and R. Pinner. Sheet Metal Ind. (England), 26, No. 268, 1731-1738 (1949)

The cleanness of a metal surface may be tested by the following methods: 1) The fluorescense test in which the article or test panel is treated with an oil-soluble fluorescent dyestuff and photographed under ultra-violet light after the stand-ard cleaning procedure which is to be tested. Clean metal appears black and cleanness is inversely proportional to the amount of fluorescence; 2) The waterspray test, developed for aluminum alloy surfaces, where a test panel is covered with a fine spray of water which con-denses as droplets on oil-covered areas, providing a pattern which will remain constant for sufficient time to allow a sketch to be made of the surface. The pattern is drawn on a paper divided into 100 squares and the cleaning efficiency calculated from the average value of five





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determinations, depending on the number of squares covered by condensation. The standard deviation which must not exceed nine is calculated by the formula:

Standard deviation = $\frac{\Sigma d^2}{}$

where d=deviation of the individual values from mean and n number of observations.

Aluminum castings showing surface porosity may result in corrosion due to contamination remaining in the pores, thus cleaning solutions possessing a low surface tension and a good penetrating power will greatly counter this type of contamination, while hot-water rinses may be beneficial in opening the metal pores and facilitating cleaning. Alloy composition and surface smoothness or roughness are other factors affecting the finishing processes of light metals.

The functions of a cleaning cycle are explained and the cleaning methods described are as follows: 1) hand solvent cleaning; 2) vapor degreasing; 3) emulsion cleaning; 4) oven cleaning; 5) acid cleaning treatments and 6) acid dips associated with alkali cleaning operations. Etching for designs by acid etching and alkali etching is discussed.-ALL.

Protective Processes for Metal Components. J. F. Stirling. Pract. Eng., 20, No. 495, 73-5 (1949) July 29.

A review of chemical methods for protecting a metal surface against corro-Phosphating processes are applicable only to ferrous articles and to zinc or zinc-coated metals, and among those described are electro-granodizing, Walterization, the titanium pre-dip technique and flexible phosphate processes. Chro-

mate passivation treatments are suitable for zinc products and in some cases applicable to cadmium plated articles also. Among other processes mentioned is the zincate treatment of aluminum and its alloys which involves immersing the metal for two minutes in sodium zincate solution at 27° C. after degreasing, chromating and rinsing. Another method of protecting small zinc articles is by depositing a brown-black film from a molybdate solution.-ZDA.

Sodium Silicates in Metal Cleaning, W. Stericker and W. R. Meyer. Met. Fin., 47,

7, 70 and 83 (1949) July

The first of these two letters answers Dr. Meyer's letter (see ZDA Abs. No. Dr. Meyer's reply. Mr. Stericker questions the evidence on which Dr. Meyer's reply is based in his comments on some work by Hazel and Stericker. Dr. Meyer, in his reply, admits the general lack of information about cleaning materials for use on zinc base die castings before plating, but stresses the need for cleaning procedure which would prevent blistering on baking .- ZDA.

Miscellaneous

5.10, 1.3

Prevention of Corrosion by Means Other Than Protective Coatings. F. L LaQue, (Inco), Paper before United Nations Scientific Conf. on Conservation and Utilization of Resources, Lake Success, Sept. 1, 1949, Can. Metals Met. Inds., 12, No. 8, 14-17. (1949) Aug. CORRO. SION, 6, 72-78 (1950) Feb.

Discussion includes control of vironment such as humidity control, de-aeration, and inhibitors, cathodic protection, design, and adjustments of com-position as means of preventing corro-sion other than by protective coatings. 77 references, 13 books.-INCO.

MATERIALS OF CONSTRUCTION

Ferrous Metals

6.2, 3.7, 3.5 Cast Iron Developments During the Past 25 Years. M. Ballay and R. Chavy. International Foundry Congress, Amsterdam, 1949, Preprint 2, 10 pp.

The review of salient developments is made on sections relating, respectively, to unalloyed and alloy grey cast irons, im-provements produced by heat-treatment of cast irons, white cast irons, heat- and corrosion-resisting cast irons. Some curves illustrate progressive improvement in quality and factors mainly responsible for such progress.-INCO.

Stainless Steels and Other Ferrous Alloys. M. H. Brown and W. B. DeLong. Ind. and Eng. Chem., 41, 2139-2146 (1949)

Reviews literature since 1947. Covers properties, structure, corrosion, and welding. 194 ref.—BLR.

6.2, 8.3, 7.2 Light Wall Stainless Tubing Used in

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a flange on stainless tubing previously cut to desired length. No. 316 stainless is specified to meet required corrosion resistance. Carbon steel flanges are coated with vinyl resin paint to resist corrosion. 6.2, 7.1, 3.5

Ferritic Steels for Gas Turbines. G. Wood & J. R. Rait. Paper before Journees Metallurgiques d'Automne de la Soc. Franc. de Metallurgie, Oct. 1948.

Rev. de Metallurgie, 46, 387-398; 463-474.

Wet Corn Processing. Heating, Piping, Air Cond. 21, No. 7, 89-90 (1949) July. Description of use of light wall stain-less steel tubing at A. E. Staley Mfg. Co., Decatur, Ill., for new work and replace-

ments, part of an extensive program of

ments, part of an executive program of modernization at this corn and soybean processing plant. New van stoning machine is utilized, which rolls and flattens

(1949) June, July.

Opens with reference to successful application of ferritic steel for discs in the De Havilland Goblin, and records the fact that D. H. has continued to use this material (Hecla 153, chromium-molybunder) denum steel) for discs in all their gas-turbines. Comparison of advantages of austenitic and ferritic steels is made. Ac-count of investigation of other ferritic steels (carbon-molybdenum, silica-chro-mium-molybdenum) and of Hecla 153 is given. Records unsuccessful attempts to modify Helca 153 (additions of vana-dium). Hadfield creep testing methods and equipment are described with notes on time-to-rupture test method. Detailed information on development and properties of 3% chromium, chromium-molybdenum-vanadium and 3% chromium, chromium-molybdenum-tungsten-vana-dium steels (latter known as HGT 3) is given. The results of the test are evaluated, with special reference to the chromium-molybdenum - tungsten-vanadium steel, and the general conclusion appears to be that considerable progress has been made in improvement of high-temperature properties.—INCO.

6.2, 7.4, 4.3, 2.3

High Duty Applications of Acid-Resisting Silicon Iron. R. V. Riley. Metallurgia, 40, No. 238, 185-188 (1949) Aug, Discussion of manufacture of silicon-

Discussion of manufacture of siliconiron heater tubes designed to carry live steam at about 100 lbs. psi. while immersed in dilute sulfuric acid includes heater tube castings, foundry technique, inspection and testing, metallurgical considerations, and British Standard siliconiron exciters. iron castings .- INCO.

Non-Ferrous Metals— Heavy

6.3 3.5

High-Temperature Bolting Materials (Nickel- and Cobalt-Rich Alloys). Ernest L. Robinson. *Proc. ASTM*, 48, 214-235 (1948); discussion, 236-238.—MA.

6.3, 3.4, 3.5

Sand-Cast Nickel Alloys for Corrosion- and Heat-Resisting Service. W. H. Richardson. Metallurgia, 40, No. 235, 3-14

Detailed information on the corrosion-and heat-resistance of Monel, nickel, Inconel, and Lang-alloy alloys 4R, 5R, and 6R is given.—MA.

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6.3, 3.7, 7.8

What Beryllium Copper Offers the Designer. J. T. Richards, Beryllium Corp. Machine Design, 21, No. 8, 117-123 (1949)

Discussion inludes application of beryllium copper alloys to non-magnetic ball bearings, adaptability to investment casting, and fabricating and heat-treating. Details are given on press-working, machining, cleaning, plating and properties of beryllium-copper. Tables include one on corrosion resistance of beryllium-copper. Graphs are given.-INCO.

Titanium—A Modern Metal. Julius J. Harwood. J. Amer. Soc. Naval Eng., 60, No. 4, 443-460 (1948).

A discussion describing in some detail the occurrence, manufacture, properties, and uses of titanium and its alloys. A list of 5 references is included.—MA.

Nickel-Base Alloys for High-Temperature Applications. A. G. Guy. Trans. ASM, 41, 125-136 (1949); discussion, 136-140.-MA.

6.3, 8.2, 7.10

Titanium. W. L. Finlay and E. L. Wemple. Paper presented at Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, April 22, 23, 1949, Springfield, Mass. Mat. and Meth., 30, No. 1, 91 (1949) July.

From the paper "Metallography and Properties of Commercially Pure Tita-nium," it was noted that titanium changes from hexagonal-close-packed to bodycentred cubic above 1620° F. (882° C.) and that titanium twins mechanically when deformed at room temperature. In this paper it is shown that the latter requires care in removing the affected surface immediately below the scratches produced in the early metallographic polishing steps before final polishing. Possible applications for titanium are as follows: airframe skins and structures where intermediate temperatures or corrosion problems are encountered, and aircraft power plants where temperatures between 300 and 800° F. (149 and 427° C.) are involved and naval or marine applications combining superior corrosion resistance and light weight; industrial equipment and other applications in which a combination of light weight, corrosion resistance, high strength and intermediate temperature properties are reguired.-ALL.

6.3, 4.1, 7.10

Progress in Titanium Told at Naval Research Symposium, T. C. Du Mond. Materials and Methods, Editorial Staff Mat. & Mthd. 29, No. 2, 45-47 (1949) Feb.

Methods of production, mechanical and chemical properties and possible applica-tions of pure commercial titanium metal are discussed.

The density, Young's modulus, and strength of titanium range between the corresponding values of 75ST aluminum and 18-8 austenitic stainless steel at intermediate temperatures. Its strength-weight ratio is better than that of aluminum and stainless steel in specific applications. Where it can be substituted directly for the latter, a weight saving of 40 percent results. Commercial titanium is readily forged, machined, and

The resistance of titanium to sea water and marine atmospheric corrosion is

better than that of austenitic stainless steel, Monel, and cupro-nickel alloys, and equal to that of platinum and Has-Commercial titanium is resistant to 95 percent nitric acid at 25° C and up to 65 percent nutre acid at 25 c. and up to 65 percent concentration at 55° C. to boiling; to relatively dilute, warm hydrochloric or sulfuric acid; to aqua regia at 30° C; to water saturated with chlorine and chlorine saturated with water at 80° C.; to bleach solution at 30° C.; and to boiling solutions of 10 c. second to boiling solutions of 10 c. percent ferric chloride, and 28 percent calcium chloride, or 10 percent sodium hydroxide.

This combination of properties would make titanium useful for airframe skins and structures, aircraft power plants operating at 150-430° C., naval and marine applications, such as condenser tubes, salt water piping, plumbing fixtures, pump rods, and antifriction bearings running in sea water, industrial equipment, and other applications where good intermediate-temperature properties, corrosion resistance, and light weight combined with high strength are required.

Production of titanium is still limited. The Kroll process, involving a reaction between titanic chloride and magnesium, yields a spongy metal which is then ground, purified, and processed by powder metallurgy. The iodide process, though producing a pure titanium, is not feasible for large-scale production. Two other methods are based on arcmelting and on the induction melting of titanium powder in graphite crucibles.

Slight impurities of certain types apparently have a profound effect upon the final properties of titanium. Alloying additions of promising value include up to 5 percent aluminum, about 5 percent manganese, and up to 1 percent beryllium, boron, and silicon. Most of these elements appreciably increase the tensile strength and some improve the coldworking properties; aluminum improves both hot and cold working properties and increases the oxidation resistance of titanium.-PDA.

6.3, 6.4

Silicon Bronzes Solve Corrosion Problems. Prod. Eng., 20, 88 (1949) Oct.

Five grades of Duronze containing tin, silicon, aluminum and arsenic in addition to copper, fill many uses where properties such as high strength, effective corrosion resistance, extreme malleability, toughness, hardness, machinability and workability are of prime importance. Combinations of materials in Duplex tubing includes use of low carbon steel, aluminum, Monel or stainless steel for outer surface and copper, brass, sili-con or aluminum bronze for inntersurface. Mfd. by Bridgeport Brass.-INCO.

6.3, 8.8, 4.6

Titanium, a New Structural Metal. E. A. Gee, J. Electrochem. Soc. 96, No. 1, 19C-21C (1949).

A report on a lecture dealing with the production, fabrication and properties of titanium. It is concluded that titanium will one day fill the gap between aluminum alloys and stainless steel as far as density and strength at intermediate temp, are concerned. Its corrosion resistance is good, particularly in sea wa-ter, and it should find application in the chemical industry.-MA.

6.3, 4.2, 3.7, 2.3

The Oxidation of Static Lead Melts.

(In German.) Wolfgang Gruhl. Zeitschrift fur Metallkunde, 40, 225-240 (1949) June.

Reviews the literature and discusses the oxidation of pure lead in air; structure of the oxide films and their effect on slagging; oxidation in pure oxygen; and effect of small additions of lithium, sodium, magnesium, calcium, aluminum, calcium, zinc, tin, antimony, bismuth, copper, and silver. Method of experimentation is described and the test results graphed and tabulated. 18 ref .-

6.3, 4.6, 4.3, 8.8 Corrosion Resistance of Commercially Pure Titanium. G. E. Hutchinson, Remington Arms Co., & P. H. Parmar, du Pont Co. Paper before NACE, Ann. Conf., Cincinnati, Apr. 11-14, 1949, Corrosion, 5, No. 10, 319-324 (1949) Oct.; Disc. 324-325.

Preliminary sea-water test data obtained at Kure Beach reveal that commercially pure titanium is practically unaffected by exposure to sea water or marine atmosphere. With respect to galvanic corrosion in sea water, titanium occupies a position between 70 copper-30 nickel and Monel in the galvanic series. Preliminary laboratory investiga-tions of the corrosion resistance of titanium in a number of media typical of the chemical process industry indicate that its behavior is generally parallel to that of austenitic stainless steels. However, this similarity is not complete: e.g., titanium is highly resistant to water-saturated Cl₂, but is attacked by concentrated sulfuric acid. Table of resistance of titanium to selected chemical reagents is given. 12 references.-IKO.

6.3, 4.3, 2.2, 2.3

Resistance of Monel, Nickel and High-Nickel Alloys to Corrosion by Sulfuric Acid. International Nickel Co., Tech-nical Bulletin T-3, Oct., 1948, 44 pages.

The performance of the above in sulfuric acid solution was determined by service experience and numerous laboratory and plant corrosion tests which are summarized. Data are tabulated and plotted. 22 ref.

The Cast Zinc Alloy Containing 2 Percent Aluminum and 1 Percent Cop-per. (In German.) Karl Löhberg. Zeitscrift fur Metallkunde, 40, 220-224 (1949) June.

Describes conditions for pressure casting of the above alloy as well as its mechanical and corrosion-resistant properties. Data are graphed and tabulated. -BLR.

Preparation and Properties of Pure Titanium. I. E. Campbell and Others. References. J. Electrochem. Soc., 93, 271-285 (1948) June.—BL.

6.3, 4.1

Zinc and Zinc Alloys. II.-Metallographic Properties. (In German.) K. Bayer, K. Löhberg, and E. Schmid (FIAT Rev. German Sci., 1939-1946: Non-Ferrous Metallurgy. II, 1948, 35-43).

A review, with many references. Separate sections deal with: a) Crystallography. The alteration in structure of alloys and manganese, copper and aluminum on extrusion and on rolling are discussed. b) Recrystallization. Pure zinc raise the alloy co recrysta the allo 2 perce show n at 350° tation aluminu the zin (B pha about b addition um hav sion. T copper phere. salt sol ganic c

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) K. hmid 1946: 5-43). Sepaallogre of lumiare zinc given a 20 percent rolling reduction shows recrystallization at room temp.; additions of copper and/or aluminum raise the recrystallization temp., e.g., the alloy containing 3 percent copper has a recrystallization temp. of 150° C., while the alloys with aluminum 10 and copper 2 percent, and aluminum 15 percent show no recrystallization on annealing at 350° C. c) Ageing Processes. Precipitation hardening in alloys containing aluminum is due to transformation of the zinc-rich aluminum solid solution (β phase) and is generally brought about by heating for 10 days at 95° C.; edditions of copper magnesium or lithi.

6.3. 4.6

Zinc and Zinc Alloys. IV.—The Classification of Zinc and Zinc Alloys. (In German). K. Bayer, K. Löhberg, and E. Schmid (FIAT Rev. German Sci., 1939-1946: Non-Ferrous Metallurgy. II, 1948, 48-54.

additions of copper, magnesium, or lithium have a retarding action. d) Corrosion. The resistance of zinc-aluminum-

copper alloys to corrosion by the atmos-

phere, water, water vapor, sea water, salt solutions, acids, foodstuffs, and organic compounds is discussed.—MA.

A review with references. Useful tables are given showing: 1) specifications of the various grades of zinc obtainable, and 2) the chemical composition, sp. gr., and mechanical properties of pressure, sand, and chill castings, and rods, wires, strip, sheet, and extrusions of alloys with aluminum, aluminum and iron, aluminum and copper, copper and lead, iron, lithium, manganese, and manganese and lead. The suitability of such alloys is

discussed in relation to: 1) castability, 2) extrusion and drawing, 3) rolling, 4) free cutting, 5) brazing, 6) corrosion-resistance, especially against water, 7) resistance to creep and high and low temp., and 8) bearing properties.—MA.

6.3, 5.9, 5.3, 5.4

Zinc and Zinc Alloys. VII.—Surface Treatment. K. Bayer, K. Löhberg, and E. Schmid (In German). (FIAT Rev. German Sci., 1939-1946: Non-Ferrous Metallurgy. II, 1948, 64-67).

A review, with references. Separate sections deal with: a) Non-Metallic Coatings. The following processes are discussed: 1) phosphatizing, 2) chromatizing, 3) sodium silicate treatment, 4) other methods, e.g., treatment in potassium ferrocyanide solution, alone or together with alkali phosphates and phosphoric acid, and 5) lacquering. b) Metallic Coatings. The electrodeposition of: 1) brass and copper, 2) nickel, 3) chromium, and 4) silver, is discussed, as well as subsequent coloring.—MA.

63 43

Nalco Metal. Corrosion, 5, No. 10, 6 (1949) Oct

Nalco metal, a new lead alloy for use in tank linings, anodes and heat exchangers in the chromium plating industry is said to be substantially more resistant to corrosive and pitting action of chromic acid solutions than other lead alloys used for the purpose. Mfd. by National Lead Co.—INCO.

6.3, 7.8

Contribution to the Knowledge of the

Corrosion Phenomena of Zinc in Leclanche Cells. C. Drotschmann. Metall, 3, Nos. 5/6, 84-87 (1948).

Experiments show that the zinc pole

Experiments show that the zinc pole of Leclanche cells reacts in two different ways: 1) Solution of Zinc. This occurs, with evolution of hydrogen, according to the equation: Zn + 2NH₄Cl - ZnCl₂ + 2NH₄^{*} → 2NH₃ + H₂. The rate of reaction depends on the purity and surface condition of the zinc, the purity and acidity of the electrolyte, and the temp.; escape of ammonia into the atmosphere allows the process to proceed more nearly to completion. The rate of reaction is usually independent of the nature of the pyrolusite. 2) Corrosion of the Zinc.—By Complex ions derived from reactions between the manganese dioxide and the electrlyte. It occurs according to the following scheme: MnO₂+OH+H^{*} - (HMnO₂)^{*} + OH^{*} (in the ammoniacal section of the cell); (HMnO₂)^{*} + OH^{*} → (MnO)^{**} + 2OH^{*} (in the acidic section of the cell); (MnO)^{**} + 2OH^{*} + Xn → Zn^{**} + MnO + 2OH^{*}; MnO + 2OH^{*} + ANH₂Cl+Zn^{**} → Zn (NH₃)₂Cl+3H₂O+MnCl₂+2NH₃. The process is dependent on the reactivity of the pyrolusite (i.e. the solubility product of MnO₂+H₂O \(\operac{1}{2}\) (HMnO₂)^{*} + OH^{*}), the temp., escape of ammonia into the atmosphere, and the rate of diffusion of HMnO₂* ions towards the zinc; it is unaffected by the nature of the zinc. In a properly constructed cell which is not being discharged, only a small amount of zinc dissolves by direct reaction with the electrolyte; the major loss of zinc occurs as a result of the corrosion process.—MA.

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Non-Ferorus Metals— Light

6.4, 1.3, 4.3, 4.6

The Manufacture and Use of Magnesium and Its Alloys, with Special Reference to the Magnesium-Zirconium-Zinc Range. C. J. P. Ball. Chem. and Ind., 1948, No. 34, 531-536; summary report of lecture and discussion, ibid., 1948, No. 13, 203.

Presented at a joint meeting of the London Sections of the Society of Chemical Industry and the Institute of Metals. The development of magnesium metallurgy is outlined, and various industrial extraction processes are reviewed; in Britain the main raw material since 1940 has been calcined magnesium hydroxide slurry, obtained by treatment of sea water with dolomite. The world produc-tion of the metal for the twelve months ending March, 1944, is estimated at 240,-000 tons, as compared with 30,000 tons for a similar period during 1939-40. Unalloyed magnesium lacks sufficient strength for engineering and unconstructional uses, but combinations with other metals have a wide range of application, the principal alloys to date being those of the magnesium-aluminum-zincmanganese and magnesium - manganese systems. Typical properties of Elektron standard and zirconium-containing alloys are tabulated and discussed, and it is considered that when the outstanding properties of magnesium are more widely realized, extraction and fabrication costs will be lowered, alloys further improved, and designs changed to take full use of the advantages afforded. In the discussion, corrosion and fire risks were mentioned. Experiments have shown that fire risks with magnesium are no greater than with aluminum. Only the corrosion effects of acid and sea water need to be considered, as under other conditions magnesium is more corrosion-resistant than iron.-MA.

6.4. 7.9

Aluminum Conduit and Accessories. J. L. Simpson. Light Metals, 12, No. 132, 40-42 (1949) Jan.

A complete rigid conduit system of outstanding quality and technical accuracy in aluminum alloy with zinc-alloy accessories has been introduced by the General Electric Company, Conduit tubing of a special aluminum-manganese alloy is corrosion resistant to a high degree and is manufactured in accordance with British Standard Specifications. It is suitable for use in domestic and industrial applications and is unaffected by salt-laden atmospheres. It requires no paint or other protection for outdoor work and its resistance to lactic acids and ammonia make it suitable for agricultural and dairy installations. Aluminum conduit will not stain walls or buildings, but must be carefully embedded in plaster, where dampness may be present. A superficial attack on the surface of the tube may occur when conduit is buried in concrete while it is still wet. There is no further corrosive attack when the concrete dries. Electrical conductivity is high and perfect continuity is obtained with screwed joints when used with the die cast zinc-alloy accessories. The aluminum conduit can be bent on a portable or bench type of bending appliance with the necessary range of formers. Threading can be carried out with the standard conduit screwing tackle.—ALL.

6.4, 3.7

Magnesium - Lithium Base Alloys— Preparation, Fabrication, and General Characteristics. J. H. Jackson, P. D. Frost, A. C. Loonam, L. W. Eastwood and C. H. Lorig. J. of Metals, 1, No. 2, 149-169 (1949) Feb.

The hexagonal, close-packed crystal lattice of magnesium can be converted to the body-centered-cubic lattice of lithium by an addition of about 10.3 percent by weight or more of lithium. Additions of lithium of between 5.7 and 10.3 percent produce a structure which is a mixture of lithium dissolved in alpha, hexagonal magnesium, and magnesium dissolved in beta, body-centered-cubic lithium.

The conversion of the crystal lattice from hexagonal to body-centered-cubic improves many of the properties of magnesium. Some of these improvements

are:

1. Increased ratio of compressive to tensile yield strength; the comprehensive yield strengths of beta-phase magnesium-lithium base alloys equal or surpass the tensile yield strengths.

2. Increased modulus of elasticity in compression so that the compressive modulus equals the tensile modulus.

3. Improved formability at room tem-

perature.

4. Improved hot- and cold-rolling and extrusion characteristics.

The corrosion resistance of most magnesium-lithium base alloys, especially those containing large quantities of zinc, silver, and/or cadmium is poor; however, it was observed that the magnesium-lithium binary alloy containing about 11 percent lithium had good corrosion resistance. This material can be used to clad and to protect anodically many of the higher strength alloys.

The magnesium-lithium base alloys containing zine, aluminum, cadmium, and/or silver, can be hardened by the precipitation of a phase, called theta, which was assigned the tentative formula MgLi.LiX where X may be any one of the elements zinc, aluminum, cadmium, or silver. The lattice parameter of theta phase varies slightly with composition and aging time. It was concluded tentatively that the theta phase is a transition structure in which large quantities of lithium are soluble.

Future research on magnesium-lithium alloys will undoubtedly be concerned with improvements in stability, workhardening capacity, and corrosion characteristics, and with efforts to employ alloying elements which are relatively inexpensive and plentiful.—ALL.

6.4, 8.9, 8.3

The Steel Shortage: Can Aluminum Help? E. D. Iliff. Northern Aluminum Company, Ltd., Metal Ind. 73, No. 22, 423-426 (1948) Nov. 26.

The use of alternative materials was one of the solutions given for the steel shortage in Britain in a memorandum to the council. Little attention was paid to light alloys despite the fact that an outstanding use of aluminum for structural purposes was exemplified in the bascule bridge at Sunderland. Another outstanding example is that of the bridge over the Saguenay River, between Arvida and Shipshaw. However, only in special cases is it economically justifiable to replace steel entirely with alumi-

num in bridge construction, the most favorable uses being for portable military bridges and moving bridges of the bascule or swing type, and also for bridges of very wide span. Cranes of all types offer opportunities of saving steel In particular overhead travelling cranes of aluminum can result in cumulative savings in new buildings because reduction in wheel loads may enable further savings to be made in the structural steel work supporting the crane rails and in operation, maintenance of crane and track are minimized and power consumption is reduced on the long travel These points are being proved at present at the Northern Aluminum Company's Rogerstone works, where nine aluminum cranes are to be installed. An example of the use of high-tensile steels quoted in the memorandum is that of the Brabazon hanger. But this structure also provides two very notable examples of the use of aluminum alloys, the door, and the framework of the plate glass window. Corrugated aluminum sheeting has much to commend it as a replacement for galvanized steel because of its longer life, high reflectivity and insulating qualities. Aluminum alloy scaffold tube also seems likely to replace steel to a considerable extent, also as tubes for electric conduits. A great many advantages are to be gained by the use of aluminum in the transportation field, both in road transport and in shipbuilding, among them the saving in weight, corrosion resistance, ease of fabrication and nonmagnetic properties. In the mining industry where portability and mobility are of great importance, aluminum skips cages and winding gear will enable smaller steel winding ropes to be used and materially decrease fuel consumption. Aluminum mine tubs will raise the capacity of haulage systems and con-serve man power. By reason of its corrosion resistance aluminum is already extensively used in the dairy industry. A considerable tonnage of steel is absorbed in the manufacture of countless small articles which could with advantage be produced in aluminum, including galvanized buckets, tanks, storage bins, and many domestic articles.—ALL

6.4

Magnesium and Magnesium Alloys Properties and Processing. (In German). W. Bulian, A. Burkhardt, A. Matting, and W. Wiederholt (FIAT Rev. German Sci., 1939-1946: Non-Ferrous Metallurgy. I, 1948, 61-72).

A comprehensive review with many references. Separate articles deal with: Structure (pp. 61-62). Magnesium-manganese, magnesium, aluminum, and an alloy containing aluminum 6, bismuth 2% are considered. Recrystallization (p. 62). The temp. of recrystallization of nesium alloys and its dependence on the degree of cold working are discussed with reference to alloys containing manganese 2%, with or without additions of cerium 0.5%. Physical Properties (p.63). The m.p. of magnesium is 1103°± 5°C. and the volume contraction on freezing is 3.97%. The diffusion coeff. of magnesium in pure aluminum, at 410° C. is 5.63×10⁻⁴ cm.2/day. Mechanical Properties (pp. 63-Particular reference is made to: a) the dependence of the E modulus on the concentration of zinc, aluminum, tin, antimony, or bismuth in the alloy b) the fatigue strength of extruded alloys containing manganese 2 and cerium 0.3%, c) the properties of alloys containing aluminum 6 and sodium or potassium 0.5%, d) the

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influence of bismuth additions to alloys containing aluminum 6%; the addition of 8% bismuth produces an alloy having a very high tensile strength, e) notch tests, f) creep tests, and g) the fatigue properties of forging and casting alloys. Corrosion Properties (pp. 66-67). Deals with the corrosion-resistance of magnesium containing impurities and of alloys with 3, 6, and 7% aluminum. Processing (pp. 67-72). A detailed review of the melting stressless deformation, welding, machining, corrosion protection (by plating, and chemical and anodic oxidation) and applications of magnesium and its alloys.—MA.

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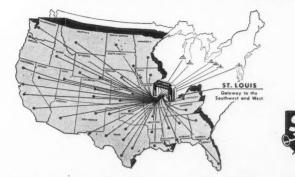
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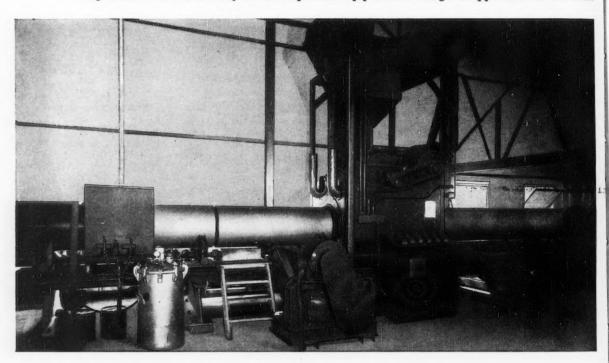
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